LLOYD'S REGISTER OF SHIPPING

LONDON

RULES AND REGULATIONS FOR THE CONSTRUCTION AND CLASSIFICATION OF STEEL SHIPS

1971

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REGISTER BOOKS AND OTHER PUBLICATIONS ISSUED BY THE COMMITTEE OF LLOYD'S REGISTER OF SHIPPING

LLOYD'S REGISTER BOOK (The Register of Ships and List of Shipowners are issued annually in July and August respectively; the Appendix in January).

The Register of Ships (in two volumes A–L and M–Z) contains the names, classes and general information concerning the ships classed by Lloyd's Register of Shipping (including the British Corporation Register); also particulars of all known ocean-going merchant ships in the world, of 100 tons gross and upwards.

The second volume (M–Z) also contains floating docks, liquefied gas carriers, ships carrying refrigerated cargo, refrigerated cargo containers, refrigerated stores and container terminals classed with Lloyd's Register and off-shore drilling rigs, as well as lists of changes of ships' names and compound names.

The Register is kept up to date by means of cumulative monthly Supplements containing the latest survey records for all classed ships, and changes of name, ownership, flag, tonnage, &c., for all ships, whether classed or not. Each Supplement is accompanied by particulars of new entries to the Register—that is, new ships and ships of which the names have been changed.

A Weekly List of Alterations in the Register of Ships is also published.

List of Shipowners contains a list of owners and managers of the ships recorded in the Register with their fleets.

The Appendix contains lists of shipbuilders with existing ships they have built; marine enginebuilders and boilermakers; dry and wet docks; telegraphic addresses and codes used by shipping firms; marine insurance companies.

Statistical Tables are issued gratis to Subscribers to the Register Book.

REGISTER OF YACHTS Published annually in April, this volume contains in addition to detailed information relating to yachts classed by the Society, the names, dimensions, etc., of other British and overseas yachts, whose particulars are known; a list of one-design and restricted classes; national authorities and list of sail numbers of certain classes of racing yachts*; geographical list of yacht clubs; list and particulars of yacht and sailing clubs with the names of officers; index of signal letters; late names of yachts; names and addresses of yacht builders and designers; list of owners with their addresses, clubs and the names of their yachts.

***LIST OF NATIONAL AUTHORITIES AND SAIL NUMBERS OF RACING YACHTS** (as published in the Register of Yachts) may be purchased separately.

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YACHT RULES

- **Vol. I:—WOOD AND COMPOSITE YACHTS (Sailing, Auxiliary, and Full Power)**
- **Vol. II:—STEEL YACHTS**
- **Vol. III:—INTERNATIONAL RATING CLASSES**
- **PROVISIONAL RULES FOR THE CONSTRUCTION OF REINFORCED PLASTIC YACHTS**
- **A GUIDE TO MACHINERY AND ELECTRICAL EQUIPMENT IN YACHTS**

REGISTER OF AMERICAN YACHTS

This Register is published annually in May from the Society's New York Office. Copies may also be obtained on application to the Manager, Lloyd's Register Printing House, Manor Royal, Crawley, Sussex, England.

This book contains the names, dimensions, and full particulars of the yachts of the United States and Canada, so far as they are ascertainable; reproductions in colour of the burgees of yacht clubs and the private signals of yachtsmen; a list of yacht clubs with the names of their officers; an index of signal letters; late names of yachts; and a list of yacht owners of the United States and Canada, with their addresses, clubs and yachts.

Also issued separately:—

Club Burgees and Private Signals (in colour).

RULES AND REGULATIONS FOR THE CONSTRUCTION AND CLASSIFICATION OF STEEL SHIPS, which contain the following:—

Chapter	
	REGULATIONS
A	General Regulations of Lloyd's Register of Shipping.
B	Classification Regulations.
C	Periodical Survey Regulations.
	CONSTRUCTION RULES
D	Steel Ships.
E	Pumping and Piping.
F	Fire Protection, Detection and Extinction.
G	Conditions for Survey of Machinery during Construction.
H	Main and Auxiliary Engines and Associated Machinery Components.
J	Boilers and other Pressure Vessels.
K	Spare Gear for Steam and Internal Combustion Machinery Installations.
L	Control Engineering Equipment.
M	Electrical Equipment and Electric Propelling Machinery.
N	Refrigerated Cargo Installations.
P	Materials for Ship Construction.
Q	Materials for Boiler, Pressure Vessel and Machinery Construction.

Appendices giving lists of Approved Manufacturers of Materials and Proving Establishments.

R Provisional Rules and Guidance Notes:

- (A) Methane Gas as fuel for the propulsion of Methane Tankers.
- (B) Plastic Pipes.
- (C) Classification of Nuclear Ships.
- (D) Metal Pipes for Water Services.
- (E) Torsional Vibration Stresses and Critical Speeds for Main and Auxiliary Oil Engines.
- (F) Classification of Floating Docks.
- (G) Propeller—Hull Clearances.
- (H) Repairs by Welding to Steel Castings for Crankshafts.

EXTRACTS FROM THE RULES:—

	CHAPTER(S)
No. 1	B and C
No. 2	B, C, D, and P (including Appendices)
No. 3	B, C, E, F, G, H, J, K, L, Q (including Appendices) and R (A, B, D, E, G and H)
No. 4	E, G, H, K, L, Q (including Appendices) and R (A, B, D, E, G and H)
No. 5	J, Q (including Appendices) and R (A and H)
No. 6	F
No. 7	L and M
No. 8	N (and Frozen Meat Stores)
No. 9	P, Q (including Appendices) and R (H)

RULES FOR STEEL TRAWLERS

RULES FOR INLAND WATERWAYS VESSELS

GEOMETRIC PROPERTIES OF ROLLED SECTIONS AND BUILT GIRDERS

Volume I British and U.S.A. Sections **Volume II** Metric Sections **Volume III** Japanese Sections

A series of curves giving section modulus and moment of inertia of a wide range of sections used in shipbuilding, in association with varying thicknesses of plating. The areas of sections (without plating) are also given.

FREIGHT CONTAINER CERTIFICATION SCHEME

PROVISIONAL REQUIREMENTS FOR THE SURVEY OF PRESSURE COMPONENTS FOR LAND-BASED NUCLEAR INSTALLATIONS

LIST OF APPROVED FUSES

LIST OF TYPE TESTED CIRCUIT-BREAKERS

CARGO HANDLING GEAR CODE

PROVISIONAL RULES FOR THE APPLICATION OF GLASS REINFORCED PLASTICS TO FISHING CRAFT

AUTOMATIC CONTROL IN SHIPS

GUIDANCE NOTES AND REQUIREMENTS FOR THE CLASSIFICATION OF AIR CUSHION VEHICLES

LIST OF TYPE APPROVED INSTRUMENTS AND CONTROL EQUIPMENT

TERMS OF SUBSCRIPTION FOR THE REGISTER BOOKS AND PRICES OF OTHER PUBLICATIONS UPON APPLICATION TO THE MANAGER, LLOYD'S REGISTER PRINTING HOUSE, MANOR ROYAL, CRAWLEY, SUSSEX, ENGLAND

LLOYD'S REGISTER OF SHIPPING

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RULES AND REGULATIONS FOR THE CONSTRUCTION AND CLASSIFICATION OF STEEL SHIPS

1971

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CHANGES EMBODIED IN PRESENT EDITION OF THE RULES

The following additions and amendments have been adopted by the Committee since the previous (1970) edition of the Rules:—

Chapter B CLASSIFICATION REGULATIONS

Classification

Section 1. Para. 101 has been amended.
A new paragraph (109) has been added.

Periodical Surveys

Section 8. Para. 802 has been amended.

Chapter C PERIODICAL SURVEY REGULATIONS

Special Surveys—Hull Requirements

Section 2. Para. 207. A new sub-paragraph has been added.

Special Surveys—Tankers

Section 3. Para. 307 has been amended.

Chapter D STEEL SHIPS

General

Section 1. Para. 109. "Fire protection, detection and extinction arrangements" has been added to the list of plans.

Longitudinal Strength

Section 3. Paras. 301 and 302 have been amended.

Carriage of Ore Cargoes

Section 3A. The Section has been revised.

Shell Plating

Section 5. Table D 5.1 has been amended.

Double Bottoms

Section 9. Para. 939. Two cross-references have been added.

Cantilevers

Section 15. Paras. 1501 to 1505 have been revised.
Para. 1506 has been amended.

Superstructures and Deckhouses

Section 17. A new paragraph (1719) has been added.

Watertight Bulkheads

Section 18. The Section has been revised.

Peak, Deep and Topside Tanks

Section 19. Paras. 1907 to 1913 have been revised.
Paras. 1926, 1931 and 1933 have been amended.
Para. 1935. A cross-reference has been added.

Watertight Tunnels

Section 20. Para. 2004. The first sub-paragraph has been amended.

Steering Gear

Section 23. Para. 2310 has been amended.

Hatchways and Deck Openings

Section 26. A new paragraph (2638) has been added.

Masts and Rigging

Section 27. Paras. 2701 and 2704 have been amended.
Para. 2709. Three sub-paragraphs have been added after the sub-paragraph defining symbol X.
Para. 2719 has been amended.
Table D 27.1. A footnote has been added.

Bulwarks, Freeing Ports, Scuppers and Sanitary Discharges and Side Scuttles

Section 28. Para. 2802 has been amended.
Para. 2805. A sub-paragraph has been added.

OIL TANKERS

General

Section 40. A new paragraph (4005) has been added.

Longitudinal Strength

Section 41. Paras. 4101, 4103 and 4104, have been amended.

Shell Plating

Section 43. Table D 43.1 has been amended.

Bottom, Side and Deck Longitudinals

Section 44. Para. 4404 has been amended.
A new paragraph (4405) has been added.

Oiltight and Non-Oiltight Bulkheads

Section 50. Paras. 5002 and 5005 have been amended.

APPLICATION OF HIGHER TENSILE STEEL

Local Strength

Section 67. Para. 6704. Two sub-paragraphs have been added.

Chapter E — PUMPING AND PIPING

Bilge and Ballast

Section 2. Para. 267. The heading has been amended.
Paras. 268 to 270 have been amended.

Oil Fuels and Cargo Oils having a F.P. above 65,5°C (150°F)

Section 3. Paras. 311 and 346 have been amended.

Boiler Feed Water Systems

Section 7. Para. 710. Three cross-references have been added.

Chapter G — CONDITIONS FOR SURVEY OF MACHINERY DURING CONSTRUCTION

Section 1. Para. 104. "Torsional vibration calculations for the shafting systems. (*See* H 241 to H 243)", has been added to the list of plans.

Chapter H — MAIN AND AUXILIARY ENGINES AND ASSOCIATED MACHINERY COMPONENTS

Shafting for Oil Engine, Turbine and Electric Propulsion Installations

Section 2. Para. 241 has been amended.

General Requirements for Oil Engines and Starting Air Compressors

Section 6. Para. 605. The heading and subject matter have been amended.
A new paragraph (607) has been added.
Para. 621 has been amended.

General Requirements for Steam and Gas Turbines

Section 8. Para. 840 has been amended.

Chapter J — BOILERS AND OTHER PRESSURE VESSELS

Manufacture and Workmanship

Section 5. The Note at the beginning of the Section has been amended.
Para. 512 has been amended.

Mountings and Fittings

Section 6. Paras. 620 and 635 have been amended.

Chapter L — CONTROL ENGINEERING EQUIPMENT

General Requirements

Section 1. Para. 102 (e) has been amended.
A new paragraph (103) has been added.
The remainder of the Chapter has been revised.

Chapter P — MATERIALS FOR SHIP CONSTRUCTION

Steel Castings

Section 5. Para. 503 has been amended.

Steel Forgings

Section 6. Para. 603, sub-paras. (*a*) and (*b*) have been amended.

Steel Wire Ropes for Standing Rigging, Towlines and Mooring Ropes

Section 9. Paras. 902 and 905 have been amended.
Table P 9.2. A note has been added.

Fibre Ropes

Section 10. Paras. 1002 and 1008 have been amended.

Aluminium Alloy Plates, Bars and Sections

Section 12. The Section has been revised.

Aluminium Alloy Rivets

Section 13. The heading has been amended as above, and the subject matter has been revised.

Welding of Aluminium Alloys

Section 14. The Section has been revised.

Chapter Q — MATERIALS FOR BOILER, PRESSURE VESSEL AND MACHINERY CONSTRUCTION

Rolled Steel Sections and Bars

Section 4. Para. 415 has been amended.

Steel Forgings

Section 6. Table Q 6.5 has been corrected.

Steel Tubes and Pipes

Section 7. Para. 709 has been amended.

Chapter R — PROVISIONAL RULES AND GUIDANCE NOTES

R(A) Methane Gas as Fuel for the Propulsion of Methane Tankers

General

Section 1. Paras. 117 and 118 have been amended.

R(E) Torsional Vibration Characteristics of Main and Auxiliary Oil Engines

Torsional Vibration Critical Speeds and Limiting Vibration Stresses

Section 1. Para. 112 has been amended.

A number of alterations of an editorial or minor nature have also been made.

J. HUXSTER,
Secretary.

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Chapter A

GENERAL REGULATIONS OF LLOYD'S REGISTER OF SHIPPING

Section 1

This Society, founded in 1760 and reconstituted in 1834, was established for the purpose of obtaining for the use of Merchants, Shipowners, and Underwriters, a faithful and accurate Classification of Mercantile Shipping. The Society continues to fulfil that purpose; and in addition approves design, surveys and issues reports on hovercraft, non-mercantile shipping, on amphibious and land installations, and on machinery, apparatus, materials and mass production methods of all kinds, for the purpose of testing their compliance with plans and specifications, or their fitness for particular requirements. This Chapter contains the General Regulations which have been from time to time adopted for the government of the Society.

Section 2

The superintendence of the affairs of the Society to be under the direction of the General Committee composed of

5 members nominated by the Chamber of Shipping of the United Kingdom as well as the Chamber's President and Vice-President *ex officio*.

13 members nominated by the London General Shipowners' Society as well as that Society's Chairman and Deputy-Chairman *ex officio*.

9 members nominated by the Committee of Lloyd's as well as the Chairman and a Deputy-Chairman of Lloyd's *ex officio*.

4 members nominated by the Institute of London Underwriters as well as the Institute's Chairman and Deputy-Chairman *ex officio*.

5 members nominated by the Shipbuilders and Repairers National Association.

3 members nominated by the National Association of Marine Enginebuilders.

40 members nominated to represent United Kingdom outports including the representation of the Liverpool and Scottish Committees.

All nominations to be subject to confirmation by the General Committee.

40 other members specially elected by the General Committee to include up to 12 International Shipowners and 5 Industrial Services representatives together with past Chairman and Deputy-Chairmen of the General Committee and Chairmen of National Committees appointed under Section 5.

The General Committee are further empowered to elect as Honorary Members of the General Committee such persons of distinction and eminence as the General Committee shall from time to time think fit.

Section 3

The General Committee reserve the right of varying the representation or *ex officio* membership on the General Committee of Shipowners and Underwriters, and of varying or withdrawing the representation or *ex officio* membership of the General Committee of all other bodies entitled to nominate members specially or *ex officio*.

Section 4

1. All members of the General Committee who have been nominated or who are members *ex officio* shall retire annually and may be renominated by their respective nominating bodies or may become *ex officio* members for the ensuing year.

2. All members elected by the General Committee are to retire at the end of four years, and are to be eligible for re-election.

Section 5

1. The General Committee to appoint Sub-Committees of Classification, to be so regulated that appointed Members of the General Committee may, in rotation, take their turn of duty thereon throughout the year.

2. The General Committee may also appoint a National Committee in any country where it appears that such a Committee could form a useful liaison between the Society and the maritime and commercial communities in that country. National Committees may consist of or include persons who are not members of the General Committee.

Section 6

The Committee to appoint from their own body a Chairman to hold office for such period as they shall determine and two Deputy-Chairmen who shall be elected annually; one Deputy-Chairman being designated Deputy-Chairman and Treasurer and the other Deputy-Chairman and Chairman of the Sub-Committees of Classification.

Section 7

The Servants of the Society to be appointed by and be under the direction of the General Committee.

Section 8

Special meetings to be convened by order of the Chairman, or one of the Deputy-Chairmen, or on the requisition of any three Members.

Section 9

All elections and appointments to be made by ballot, if demanded, excepting when, in the election of Chairman or one of the Deputy-Chairmen, only one person is nominated for each office.

Section 10

1. The General Committee to be empowered:—

(*a*) At any time, and from time to time, to delegate all or any of their powers to an Executive Board consisting of such members of the General Committee and to be selected in such manner as the General Committee may think fit, and to make Regulations for the meetings, proceedings and other activities of such Executive Board, and

(*b*) to make such By-Laws for their own government and proceedings and for representation from the outports as they may deem requisite; but no new Rule or By-Law to be introduced or any Rule or By-Law altered, without special notice being given for that purpose at the meeting of the General Committee next preceding that at which such motion is intended to be made; such notice to be inserted in the summons convening the meeting.

Section 11

No new Rule, or alteration in any existing Rule materially affecting the classification of ships, to be applied compulsorily to ships of which the plans have been submitted and approved before the expiration of six months after the date when the change has been adopted.

Section 12

A Register Book to be printed annually for the use of Subscribers, containing the names of the ships with other useful information, and the character assigned, where the ships are classed by the Society; also the names, etc., of ships of 100 gross registered tons and upwards which are not classed with the Society.

The terms of subscription to be such annual sum or sums as may from time to time be determined by the General Committee.

Section 13

TECHNICAL COMMITTEE

1. The Technical Committee to be constituted as follows:—

Ex-officio—	Ship-owners	Under-writers	Ship-builders	Engineers	Others	TOTAL
The Chairman of Lloyd's Register...	–	1	–	–	–	1
The Deputy-Chairman and Chairman of the Sub-Committees of Classification of Lloyd's Register	1	–	–	–	–	1
The Deputy-Chairman and Treasurer of Lloyd's Register	1	–	–	–	–	1
Nominated by—						
The General Committee of Lloyd's Register	5	3	2	2	–	12
The Royal Institution of Naval Architects	–	–	1	1	–	2
The North-East Coast Institution of Engineers and Shipbuilders	–	–	1	1	–	2
The Institution of Engineers and Shipbuilders in Scotland	–	–	1	1	–	2
The Shipbuilders and Repairers National Association ...	–	–	5	–	2	7
The National Association of Marine Enginebuilders ...	–	–	–	3	–	3
The Institute of Marine Engineers	–	–	–	2	–	2
The British Internal Combustion Engine Manufacturers' Association	–	–	–	1	–	1
The Society of Consulting Marine Engineers and Ship Surveyors	–	–	–	1	–	1
The Iron and Steel Institute	–	–	–	–	1	1
The British Steel Corporation	–	–	–	–	1	1
The British Independent Steel Producers' Association ...	–	–	–	–	1	1
The Honourable Company of Master Mariners	–	–	–	–	1	1
The Institution of Electrical Engineers	–	–	–	–	1	1
The British Electrical and Allied Manufacturers' Association	–	–	–	–	1	1
The Technical Committee	3	–	2	2	–	7
The Technical Committee (from other countries abroad)	–	–	–	–	8	8
	10	4	12	14	16	56

The above nominations to be subject to confirmation by the General Committee.

In addition to the foregoing:—

(*a*) Each National Committee appointed under Section 5, may appoint a representative to attend meetings of the Technical Committee.

(*b*) Further persons may, with the consent of the General Committee, be co-opted to serve on the Technical Committee.

2. The function of the Technical Committee is to consider any technical problems connected with the Society's business and any proposed alterations in the existing Rules, or to frame new Rules, for the classification, survey and building of ships (hull and machinery).

3. The term of office of all Members to be four years, one-fourth retiring each year, the Members so retiring to be eligible for renomination for a second term. Unless specially so authorised by the General Committee, no Member, other than Chairmen and/or Vice-Chairmen, who has served for two periods of four years to be eligible for renomination for a third term until after the expiration of at least one year. In the event of any vacancy occurring before the expiration of a term of four years a representative to be nominated to fill the vacancy for the unexpired portion of the term.

4. Technical Directors and Superintendents nominated by the Technical Committee, or those who are partners in firms, or directors or managers of joint stock companies, or of similar status, to be eligible for membership.

5. The Technical Committee to appoint from their own body, biennially, a Chairman, or two alternative Chairmen, who must be a Member, or Members, of the General Committee, and, if desired, a Vice-Chairman or two alternative Vice-Chairmen, who need not be Members of the General Committee. The same Members not to be eligible to hold office for more than four years in succession, unless on the occasion of the third election a ballot—to be taken whether there be any other candidates or not—shows a majority in their favour of at least three-fourths of the Members present. The appointment of all Chairmen and Vice-Chairmen to be confirmed by the General Committee.

6. Meetings of the Technical Committee to be convened as often and at such times and places as may appear necessary, but there shall be at least two meetings in each year.

7. Members desiring to propose alterations in, or additions to, the Rules for the classification, survey or building of ships (hull and machinery) shall give notice of all such proposals in writing to the Secretary.

Every meeting to be convened by notice from the Secretary, if possible one month before the date of meeting; and the Secretary to send to each Member an agenda paper as soon as possible thereafter.

8. Any proposals of the Technical Committee involving any amendment of, or addition to, the Rules for the classification, survey or building of ships (hull and machinery) to be reported to the General Committee, who will refer them to a special meeting of the General Committee, as required by Section 10(b) of this Chapter.

9. The Technical Committee to be empowered:—

(i) to draw up, if they so desire, By-Laws for governing procedure at Meetings;

(ii) to appoint Panels of the Committee;

(iii) to co-opt to the main Committee, or to such Panels, representatives of any organisation or industry or private individuals for the purpose of considering any particular problem.

10. The General Committee reserve to themselves the right of varying, adding to, or rescinding, at their discretion, any or all the Regulations in this Section including the representation of the bodies mentioned in Para. 1.

Section 14

All reports of survey are to be made by the Surveyors according to the form prescribed, and submitted for the consideration of the General Committee, or of the Sub-Committees of Classification, but the character assigned by the latter to be subject to confirmation by the General Committee or by the Chairman acting on behalf of the General Committee.

Section 15

The reports of the Surveyors (and all documents and proceedings relating to the classification of ships) are to be carefully preserved and shall, subject to the approval, in his absolute discretion, of the Chairman or one of the Deputy-Chairmen, be open to the inspection of the Owner and of any other person authorised in writing by the Owner.

Copies of reports will, subject to the approval of one of the Chairmen as indicated above, be supplied to Owners, or their representatives, on application.

Section 16

The Surveyors to the Society are not to be permitted (without the especial sanction of the General Committee) to receive any fee, gratuity, or reward whatsoever, for their own use or benefit, for any service performed by them in their capacity of Surveyors to this Society, on pain of immediate dismissal.

Section 17

The Committees of the Society use their best endeavours to ensure that the functions of the Society are properly executed, but is it to be understood that neither the Society nor any Member of any of its Committees, nor any of its Officers, Servants or Surveyors is under any circumstances whatever to be held responsible or liable for any inaccuracy in any report or certificate issued by the Society or its Surveyors or in any entry in the Register Book or other publication of the Society, or for any act or omission, default or negligence of any of its Committees or any Member thereof, or of the Surveyors, or other Officers, Servants or Agents of the Society.

Section 18

The funds and accounts to be under the authority and control of the General Committee.

Section 19

Fees are chargeable for all surveys held by the Society's Surveyors at ports in the United Kingdom in accordance with established scales.

For all surveys held at ports abroad fees will be chargeable according to the nature and extent of the services rendered.

Travelling expenses incurred by the Surveyors in connection with the above services are also chargeable.

Section 20

The class of a ship is liable to be withheld, or, if already granted, may be withdrawn from the Register Book, in the case of non-payment of any fees or expenses chargeable on account of such ship.

21st May, 1970

Chapter B

CLASSIFICATION REGULATIONS

Section 1

CLASSIFICATION

General

101 Steel ships built in accordance with the Society's Rules and Regulations, or with alternative arrangements equivalent thereto (*see* B 501), will be assigned a class in the Register Book and will continue to be classed so long as they are found, upon examination at the prescribed annual and other periodical surveys, to be maintained in a fit and efficient condition and in accordance with the requirements of the Rules.

The Committee, in addition to requiring compliance with the Society's Rules, may require to be satisfied that very small ships, or ships of special type are suitable for the geographical limits of service contemplated.

Classification will be conditional upon compliance with the Society's requirements in respect of both hull and machinery (i.e., main and auxiliary engines including torsional vibration characteristics, boilers, essential appliances, pumping arrangements and electrical equipment).

The Rules are framed on the understanding that ships will be properly loaded and handled; they do not, unless stated in the class notation, provide for special distributions or concentrations of loading. The Committee may also require additional strengthening to be fitted in any ship which, in their opinion, may be subjected to severe stresses due to particular features in her design or when it is desired to make provision for exceptional loaded or ballasted conditions. In these cases particulars are to be submitted for consideration.

The Committee cannot assume responsibility for stability, trim, hull vibration or other technical characteristics not covered by the Rules, but they are willing to advise on these matters. They are also willing to act in respect of national and international statutory safety and other requirements for passenger and cargo ships governing arrangements not covered by the Society's Rules.

Character of Classification and Class Notations

102 Class 100A1. This class will be assigned to sea-going ships built in accordance with the Society's Rules and Regulations for the draught required.

103 Class 100A1 oil tanker. This class will be assigned to sea-going tankers intended to carry oil in bulk and built in accordance with the Society's Rules and Regulations for the draught required.

Where the scantlings and arrangements have been approved by the Committee for the carriage of oil having a flash point above 65,5°C (150°F), or other liquid cargoes in bulk, the class notation affixed to the character will be suitably modified to show the nature of the cargo.

104 Class 100A1 liquefied gas carrier, type of gas(es) in independent tanks, maximum vapour pressure, minimum temperature and where necessary maximum temperature (to be specified). This class will be assigned to sea-going ships specially designed for the carriage of liquefied petroleum, natural or other gases and built in accordance with the Society's Rules and Regulations for the draught required.

105 Class 100A1 ore carrier. This class will be assigned to sea-going ships specially designed for the carriage of ore and built in accordance with the Society's Rules and Regulations for the draught required.

106 Class 100A1 trawler, 100A1 stern trawler, 100A1 fishing vessel. These classes will be assigned to ships built in accordance with the appropriate Rules and Regulations for the Construction of Steel Trawlers.

107 Class 100A1 tug. This class will be assigned to all sea-going tugs built in accordance with the Society's Rules and Regulations for such ships.

108 Class 100A1 dredger, 100A1 hopper dredger, 100A1 hopper barge. These classes will be assigned to dredgers and hopper barges built in accordance with the Society's Rules and Regulations for such ships.

109 Class 100A1 icebreaker. This class will be assigned to sea-going ships specially designed for icebreaking duties, and built in accordance with those Sections of the Society's Rules and Regulations appropriate to such ships, and other special requirements as may be approved by the Committee for the proposed service.

110 Class 100A1 for restricted service or for special purposes. This class will be assigned to sea-going ships intended to operate within specific limits or for special purposes and built in accordance with the Society's Regulations and the scantlings, arrangements and equipment specially approved by the Committee for such ships. The class notation affixed to the character in the Register Book will indicate the geographical limits of the service or the particular purpose for which the class is assigned.

111 Class A1 for restricted service. This class will be assigned to ships intended to trade only within specially sheltered waters, such as harbours, rivers or estuaries, provided the scantlings, arrangements and equipment are approved by the Committee as suitable for such service. The class notation affixed to the character will indicate the geographical limits for which the ship has been approved.

112 Special cargoes. When the scantlings and arrangements have been approved for cargoes of a special nature an appropriate class notation will be entered in the Register Book.

113 Special features. When a special feature in the design or construction of a ship or its machinery has been approved, an appropriate class notation may be entered in the Register Book.

114 Corrosion control. Where an approved method of corrosion control is fitted and an appropriate reduction in scantlings has been permitted, the notation (cc) will be entered in the Register Book.

115 Strengthening for Navigation in Ice. Where an ice class notation is desired, additional strengthening is to be fitted in accordance with the special requirements given in the Rules which are based on Baltic conditions. Four classes of ice strengthening are detailed in the Rules:—

Ice Class 1* strengthening is for ships intended to navigate in extreme ice conditions.

Ice Class 1 strengthening is for ships intended to navigate in severe ice conditions.

Ice Class 2 strengthening is for ships intended to navigate in intermediate ice conditions.

Ice Class 3 strengthening is for ships intended to navigate in light ice conditions.

It is the responsibility of the Owner to determine which notation is most suitable for his requirements.

Section 2

EQUIPMENT

201 The figure 1 in the character of classification assigned to a ship indicates that her equipment of anchors, chain cables and hawsers is in good and efficient condition and in the cases of ships not classed for a special or restricted service, in accordance with the requirements of the Rules. In the case of ships classed for a special or restricted service, the figure 1 indicates that the equipment has been approved by the Committee as suitable for the particular service.

202 When the equipment of a ship is not supplied or maintained in accordance with the requirements of the Rules but is considered by the Committee to be acceptable for the particular service, the Committee may agree to the figure 1 being omitted and a line inserted after the character, thus, 100A–. In cases where the equipment is found to be seriously deficient in quality or quantity, the class of the ship will be liable to be withheld from the Register Book. Special consideration will be given to ships intended to be classed for which, by reason of their particular purpose or service, normal equipment may be unnecessary. In such cases the figure 1 may be omitted from the character of classification, viz., 100A.

Section 3

MACHINERY

301 (*a*) The machinery, as defined in B 101, is to be constructed and installed on board ship in accordance with the Society's Rules and Regulations. On satisfactory completion of trials, an appropriate class notation will be assigned in the Register Book, thus, LMC (Lloyd's Machinery Certificate).

(*b*) Where arrangements are such that essential machinery can be operated by remote and/or automatic control equipment the control equipment is to be arranged, installed and tested in accordance with the Society's Rules and Regulations.

(*c*) When arrangements are such that the ship can be operated with the machinery spaces unattended (*see* Chapter L) a notation "UMS" will be assigned in the Register Book unless the Owner expresses a wish to the contrary. Non-compliance with the relative sections of Chapter L will not affect the LMC notation since the Society's Rules require that the essential machinery can be operated satisfactorily with the control system(s) out of action.

Section 4

MATERIALS

401 The materials used in the construction of hulls and machinery intended for classification, or in the repair of ships already classed, are to be of good quality and free from defects and are to be tested in accordance with the requirements of Chapters P and Q. The steel is to be manufactured by an approved process at works recognised by the Committee. Alternatively, tests to the satisfaction of the Committee will be required to demonstrate the suitability of the steel.

Section 5

EQUIVALENT ARRANGEMENTS

501 Alternative arrangements will be permitted, provided they are considered by the Committee to be equivalent to the Society's requirements.

Section 6

NEW CONSTRUCTION

Submission of Plans

601 When it is intended to build a ship for classification with the Society, constructional plans and particulars of the hull, equipment and machinery (*see* B 101), as detailed in the Rules, are to be submitted through the local Surveyors for the approval of the Committee before the work is commenced.

Any subsequent modifications to the scantlings, arrangements or equipment shown on the approved plans are also to be submitted for approval.

Use of Approved Items of Machinery

602 Machinery may incorporate items which have been type tested and approved by the Committee.

Constructional plans and particulars of approved items need not be included in submissions made in accordance with 601.

Novel Forms of Construction

603 Where the proposed construction of any part of the hull or machinery is novel in design, or involves the use of unusual material, or where experience, in the opinion of the Committee, has not sufficiently justified the principle or mode of application involved, special tests or examinations before and during service may be required. A suitable notation will be inserted in the Register Book when the Committee consider this necessary.

Special Survey during Construction

604 New ships intended for classification are to be built under the Society's Special Survey and when classed will be entitled to the distinguishing mark ✠ inserted before the character in the Register Book, thus: ✠100A1.

From the commencement of the work until the completion of the ship, the Surveyors are to examine the materials, workmanship and arrangements. Any items not in accordance with the Rules or the approved plans, or any material, workmanship or arrangement found to be unsatisfactory are to be rectified.

New machinery for ships classed or intended for classification is to be constructed under the Society's Special Survey, and on completion will be entitled to the distinguishing mark ✠ inserted before the machinery class notation in the Register Book, thus: ✠LMC.

The Special Survey during construction of the machinery shall relate to the period from the commencement of the work until the final test under working conditions. Any items not in accordance with the Rules or the approved plans, or any material, workmanship or arrangement found to be unsatisfactory are to be rectified.

Date of Build

605 The date of completion of the Special Survey during Construction of ships built under the Society's inspection will normally be taken as the date of build to be entered in the Register Book. If the period between launching and completion or commissioning is, for any reason, unduly prolonged, the dates of launching and completion or commissioning may be separately indicated in the Register Book.

When a ship upon completion is not immediately put into commission, but is laid up for a period, the Committee, upon application by the Owner, prior to the ship proceeding to sea, may direct an examination of the ship to be made in dry dock by the Society's Surveyors. If, as the result of such survey, the hull and machinery be reported in all respects free from deterioration, the subsequent Special Survey and Complete Survey of the machinery will date from the time of such examination.

Section 7

CLASSIFICATION OF SHIPS NOT BUILT UNDER SURVEY

701 The requirements of the Committee for the classification of ships which have not been built under the Society's survey are set forth in C 12.

Section 8

PERIODICAL SURVEYS

Annual Surveys

801 All steel ships are to be surveyed at intervals of approximately one year, in accordance with the requirements set forth in C 1.

Docking Surveys

802 Owners should notify the Society whenever a ship can be examined in dry dock or on a slipway. It is desirable that ships should be examined in dry dock at intervals of about 12 months; the maximum interval is to be two years, except that where a suitable high resistance paint is applied to the underwater portion of the hull and an approved automatic system of impressed current external cathodic protection is fitted, this maximum interval may be extended to about $2\frac{1}{2}$ years at the discretion of the Committee.

Attention should also be given to any relevant statutory requirements of the National Authority of the country in which the ship is registered.

This regulation is not applicable to ships operating in fresh water or to certain non-propelled craft; the interval between drydockings for these ships may be greater than is stated above.

The date of the last examination in dry dock or on a slipway will be recorded in the Supplement to the Register Book.

Special Surveys

803 All steel ships classed with the Society are also to be subjected to Special Surveys in accordance with the requirements set forth in C 2 to C 8. These surveys become due at 4-yearly intervals, the first 4 years from the date of build or date of Special Survey for Classification, and thereafter 4 years from the date of the previous Special Survey.

Period allowed for completion of Special Surveys

804 When it is inconvenient for Owners to fulfil all the requirements of a Special Survey at its due date, the Committee will be prepared to consider its postponement, either wholly or in part, provided that the Society's Surveyors are afforded an opportunity, about the due date, of assessing the general condition of the hull. For this purpose the Committee will normally call for a general examination of the ship, including drydocking, of sufficient extent to be assured that her condition is satisfactory for the period of grace desired, which is not to exceed 12 months from the due date.

Special Surveys which are commenced prior to their due date are not to extend over a period greater than 12 months, except with the prior approval of the Committee, who will be prepared to consider suitable arrangements for carrying out Special Surveys over an extended period in the case of ships engaged on a regular schedule.

Record of Special Surveys

805 Ships which have satisfactorily passed a Special Survey will have a record entered in the Supplement to the Register Book indicating the date. At each Special Survey of dry cargo ships over 20 years old and tankers over 10 years old at which the prescribed requirements for determining the thickness of the structure will have been complied with, the record "TD" (thickness determination) will be entered. Where a Special Survey is not completely carried out at one time, the date recorded in the Supplement will be the date at which the principal part of the requirements is complied with. Records of Special Survey will not be assigned until the Society's requirements for machinery surveys detailed in 807 or 808 are satisfactorily completed.

Continuous Surveys

806 When, at the request of Owners, it has been agreed by the Committee that the complete survey of the hull may be carried out on the Continuous Survey basis, all compartments of the hull should be opened for survey and testing in rotation with an interval of five years between consecutive examinations of each part.

If the examination during Continuous Survey reveals any defects, further parts are to be opened up and examined as considered necessary by the Surveyor.

Ships which have satisfactorily completed the cycle will have a record entered in the Supplement to the Register Book indicating the date of completion.

Surveys of Machinery

807 Machinery, as defined in B 101, is to be submitted to the surveys described in C 5 to C 11.

Complete Surveys of machinery become due at 4-yearly intervals, the first one 4 years from the date of build or date of first Classification as recorded in the Register Book, and thereafter 4 years from the date of the previous Complete Survey. Whether or not Complete Surveys are commenced prior to their due date, they are not to extend over a period greater than 12 months without the approval of the Committee. On satisfactory completion of a survey an appropriate

record will be made in the Supplement to the Register Book. When a Complete Survey is not carried out at one time the date recorded in the Supplement will be that by which the major portion of the survey has been held.

If it is found desirable that any part of the machinery should be again examined before the due date of the next survey, a certificate for a limited period will be granted in accordance with the nature of the case.

When it is inconvenient for Owners to fulfil all the requirements of a Complete Survey at its due date, the Committee will be prepared to consider its postponement, either wholly or in part, provided that the Society's Surveyors are afforded an opportunity, about the due date, of assessing the general condition of the machinery. For this purpose the Committee will normally require a general examination to be made of sufficient extent to assure them that the condition of the machinery is satisfactory for the period of grace desired, which is not to exceed 12 months from the due date. This general examination will usually include any item which has not been surveyed for 5 years, together with any item in respect of which the 5-year interval would otherwise be exceeded during the period of postponement.

Continuous Surveys of Machinery

808 When, at the request of Owners, it has been agreed by the Committee that the complete survey of the machinery may be carried out on the Continuous Survey basis, the various items of machinery should be opened for survey in rotation, so far as practicable, to ensure that the interval between consecutive examinations of each item will not exceed five years. In general, approximately one-fifth of the machinery should be examined each year.

In such cases a record indicating the date of completion of the Continuous Survey cycle will be made in the Supplement to the Register Book.

If any examination during Continuous Survey reveals defects, further parts are to be opened up and examined as considered necessary by the Surveyor and the defects are to be made good to his satisfaction.

Upon application by Owners the Committee may agree to an arrangement whereby, subject to certain conditions, some items of machinery may be examined by the Chief Engineer of the ship at ports where the Society is not represented or, where practicable, at sea, and a limited confirmatory survey carried out at the next port of call where an Exclusive Surveyor is available. Particulars of the arrangement may be obtained from the Society's Head Office.

Boiler, Steam Pipes and Screw Shaft Surveys

809 Boiler Surveys, examination of Steam Pipes and Screw Shaft Surveys should be carried out as set forth in C 9, C 10 and C 11. On satisfactory completion, appropriate records will be made in the Supplement to the Register Book.

Section 9

REFRIGERATION

901 On application from Owners, refrigerated cargo installations which comply with Chapter N of the Rules and are favourably reported on by the Surveyors will be assigned an appropriate class in accordance with N 1. Certificates will be issued and the class notation, together with the particulars of the installation, will be entered in the Supplement.

902 The class assigned will be retained provided the installation is found to be in a good and efficient condition at the Periodical, Loading Port and other Surveys set forth in N 8.

903 The paragraphs in B 14 regarding Withdrawal of Class and in B 15 regarding Reclassification, apply also to Refrigerated Cargo Installations.

Section 10

REPAIRS AND ALTERATIONS

Repairs

1001 All repairs to hull, equipment and machinery which may be required in order that a ship may retain her class are to be carried out under the inspection of, and to the satisfaction of, the Society's Surveyors. When repairs are effected at a port where there is no Surveyor to this Society, the ship is to be surveyed by one of the Society's Surveyors at the earliest opportunity.

1002 When at any survey the Surveyors consider repairs to be necessary, either as a result of damage, or of wear and tear, they will communicate their recommendations at once to the Owners, or their representative, and if compliance therewith cannot be arranged, immediate notification will be given by the Surveyors to the Committee.

1003 If a ship which is classed with the Society is damaged to such an extent as to necessitate towage outside port limits, it shall be the Owner's responsibility to notify Lloyd's Register at the first practicable opportunity.

Alterations

1004 Plans and particulars of any proposed alterations to the approved scantlings and arrangements of hull, equipment, or machinery, are to be submitted for approval and such alterations are to be carried out under the inspection of, and to the satisfaction of, the Society's Surveyors.

Section 11

APPEAL FROM SURVEYORS' RECOMMENDATIONS

1101 If the recommendations of the Society's Surveyors are considered in any case to be unnecessary or unreasonable, appeal may be made to the Committee, who may direct a special examination to be held.

Section 12

NOTICE OF SURVEYS

1201 It is the responsibility of Owners to ensure that all surveys necessary for the maintenance of class are carried out at the proper time under the supervision of the Society's Surveyors.

It is, however, the normal practice of the Society to give timely notice to Owners when Special Surveys become due, but the non-receipt of such notice, or of notice regarding other surveys, does not absolve Owners from this responsibility.

Section 13

CERTIFICATES

1301 When the required reports on completion of the Special Surveys of new ships, or of existing ships submitted for classification, have been received from the Surveyors and approved by the Committee, certificates of first entry of classification, signed by the Chairman, Deputy-Chairman and Treasurer, or Deputy-Chairman and Chairman of the Sub-Committees of Classification, and countersigned by the Secretary, will be issued to Builders or Owners.

1302 Certificates of class maintenance in respect of completed periodical surveys of hull and machinery will also be issued to Owners on application.

1303 The Society's Surveyors are permitted to issue provisional certificates to enable a ship, classed with the Society, to proceed on her voyage provided that, in their opinion, she is in a fit and efficient condition. Such certificates will embody the Surveyor's recommendations for continuance of class, but in all cases are subject to confirmation by the Committee.

Section 14

WITHDRAWAL OF CLASS

Owners' Requests

1401 When the class of a ship, for which the Regulations as regards surveys on hull, equipment and machinery have been complied with, is withdrawn by the Committee in consequence of a request from the Owners, the notation "Class withdrawn at Owners' request" (with date) will be made in the Supplement and the notation "LR class withdrawn—Owners' request" (with date) will be made in the next reprint of the Register Book. After one year the notation will be altered to "Classed LR until" (with date).

Non-Compliance with the Regulations

1402 When the Regulations as regards surveys on the hull or equipment or machinery have not been complied with and the ship thereby is not entitled to retain her class, the class will be withdrawn and the notation "Class withdrawn" (with date) will be made in the Supplement and the notation "LR class withdrawn" (with date) will be made in the next reprint of the Register Book. After one year the notation will be altered to "Classed LR until" (with date).

Reported Defects

1403 When it is found from reported defects in the hull or equipment or machinery that a ship is not entitled to retain her class in the Register Book, and the Owners fail to repair such defects in accordance with the Society's requirements, the class will be withdrawn and the notation "Class withdrawn—Reported defects" (with date) will be made in the Supplement and the notation "LR class withdrawn—Reported defects" (with date) will be made in the next reprint of the Register Book. After one year the notation will be altered to "Classed LR until" (with date).

Infringement of Freeboard Conditions

1404 Where any ship proceeds to sea with a less freeboard than that approved by the Committee or where the freeboard marks are placed higher on the ship's sides than the position assigned or approved by the Committee, the ship's class will be liable to be withdrawn.

Section 15

RECLASSIFICATION OF SHIPS

1501 When reclassification is desired for a ship for which the class previously assigned has been withdrawn, the Committee will direct a Special Survey for Reclassification, appropriate to the age of the ship and the circumstances of the case, to be carried out by the Society's Surveyors.

If at such survey the ship be found or placed in a good and efficient condition in accordance with the requirements of the Rules and Regulations the Committee will be prepared to reinstate her original class or assign such other class as may be deemed necessary.

The date of reclassification will be recorded in the Supplement to the Register Book.

21st May, 1970

Chapter C

PERIODICAL SURVEY REGULATIONS

Section 1

ANNUAL AND DOCKING SURVEYS

Annual Surveys

101 Annual Surveys as required by B 801 should, whenever practicable, be held concurrently with statutory annual or other load line surveys.

102 The Surveyor is to satisfy himself as to the efficient condition of the following:—

Hatchways on freeboard and superstructure decks, ventilator and air pipe coamings, exposed casings, fiddley openings, skylights, flush deck scuttles, deckhouses and companionways, superstructure bulkheads, side, bow and stern doors, side scuttles and deadlights, ash shoots and other openings, together with all closing appliances.

Means of ensuring watertightness of steel hatch covers.

Scuppers and sanitary discharges (so far as practicable) with valves; guard rails and bulwarks; freeing ports, gangways and lifelines; fittings and appliances for timber deck cargoes.

The Surveyor should satisfy himself regarding the freeboard marks on the ship's side.

103 Attention is to be paid to all parts of rod and chain gears. All pins are to be examined and the chain in the vicinity of the blocks is to be cleaned and examined for wear and tear. Any length of chain so worn that its mean diameter at its most worn part is reduced to the size given in Table D 34.2, is to be renewed.

All replacements of chains are to be subjected, under the Society's supervision, to the proof tests as set forth for short-link cables in P 8 and the certificates are to be produced. It is recommended that, in addition, the breaking test as required in P 8 should be applied to these chains, and that the tests be made at a proving establishment recognised by the Committee.

It is recommended that repaired chains be tested by the repairers and a certificate to that effect produced.

It is recommended that a set of spares be provided.

The various parts of the auxiliary steering gear are to be assembled and examined in order to ascertain that the gear is in good and workable condition.

104 The Surveyor is to examine internally a forward and an after hold or tank at the second Annual Survey after the fourth and subsequent Special Surveys on a dry cargo ship and the third and subsequent Special Surveys on a tanker.

Docking Surveys

(*See* B 802)

105 When a ship is in dry dock or on a slipway she is to be placed on blocks of sufficient height, and proper staging is to be erected as may be necessary for the examination of the shell plating, sternframe and rudder.

Attention is to be given to parts of the structure particularly liable to excessive corrosion or to deterioration from causes such as chafing and lying on the ground and to any undue unfairness of the plating of the bottom.

GENERAL

106 At Annual and Docking Surveys the Surveyor should examine the ship so far as is practicable in order to satisfy himself as to her general condition.

107 When chain cables are ranged the anchors and cables should be examined by the Surveyor.

108 The requirements for the survey of main and auxiliary engines, boilers and electrical equipment are set forth in C 5 to C 11.

ANNUAL AND BIENNIAL SURVEYS OF FIRE EQUIPMENT

109 The arrangements for fire protection, detection and extinction in passenger ships are to be examined annually; in cargo ships the arrangements for fire detection and extinction are to be examined biennially.

Surveys carried out by the National Authorities of the countries in which ships are registered may be accepted as meeting these requirements.

SURVEYS FOR DAMAGE OR ALTERATIONS

110 At any time when a ship is undergoing damage repairs or alterations, any exposed parts of the structure normally difficult of access should be specially examined, e.g., if any part of the main or auxiliary machinery, including boilers, or insulation or fittings is removed for any reason the steel structure in way should be carefully examined by the Surveyor, or when cement in the bottom or covering on decks is removed the plating in way should be examined before the cement or covering is relaid.

Section 2

SPECIAL SURVEYS—HULL REQUIREMENTS

(For Tankers, see also C 3.)

(A) **At the Special Survey of ships under 5 years old.**—THE REQUIREMENTS OF AN ANNUAL SURVEY (*see* 102 and 103) ARE TO BE COMPLIED WITH, IN ADDITION TO THE FOLLOWING:—

201 The ship is to be placed on blocks of sufficient height in a dry dock, or on a slipway; proper staging is to be erected as necessary and the shell plating, sternframe and rudder are to be examined.

The rudder is to be lifted for examination of pintles if considered necessary by the Surveyor.

202 The holds, 'tween decks, peaks, deep tanks, engine and boiler spaces, coal bunkers and other spaces are to be cleared and cleaned as necessary and examined. The bilges and limbers all fore and aft are to be cleaned and the structure examined. Platform plates in engine and boiler spaces are to be lifted as may be necessary for the examination of the structure below.

Where necessary close and spar ceiling, lining and pipe casings are to be removed for examination of the structure.

203 In ships having a single bottom, a sufficient amount of close ceiling is to be lifted all fore and aft on each side from the bottom and bilges to permit the structure below to be examined.

204 In ships having a double bottom, a sufficient amount of ceiling is to be removed from the bilges and inner bottom to enable the condition of the plating to be ascertained. If it is found that the plating is clean and in good condition, and free from rust, the removal of the remainder of ceiling may be dispensed with. The Surveyor may waive the removal of heavy reinforced compositions if there is no evidence of leakages, cracking or other faults in the composition.

205 The steelwork is to be exposed and cleaned as may be required for its proper examination by the Surveyor. Careful examination is to be made of parts of the structure particularly liable to excessive corrosion or to deterioration from causes such as chafing, lying on the ground, or handling of cargo.

Attention is to be given to the shell plating in way of side, bow and stern doors, ash shoots and other openings.

The Surveyor may require to ascertain by drilling or other approved means, the thickness of the material in any portion of the structure where signs of wastage are evident or wastage is normally found. Any parts of the structure which are found defective or materially reduced in scantlings are to be made good by materials of the approved scantlings and quality. Attention is to be given to the structure in way of discontinuities. Surfaces are to be recoated as necessary.

206 In cases where the inner surface of the bottom plating is covered with cement, asphalt, or other composition, the removal of this covering may be dispensed with, provided it be inspected, tested by beating or chipping, and found sound and adhering satisfactorily to the steel.

207 Double bottom compartments, peak tanks and all other tanks are to be tested by a head sufficient to give the maximum pressure that can be experienced in service.

Tanks may be tested afloat provided their internal examination is also carried out afloat.

Tanks forming part of the main structure, except as stated below, are to be cleaned and examined internally, special attention being given to tanks under boiler spaces. Tanks (excluding peak tanks) used exclusively for oil fuel or for oil fuel and fresh water ballast need not be examined internally provided, after external examination and testing in accordance with the requirements set out above, the Surveyor finds the condition of these compartments satisfactory.

Double bottom tanks used for oil fuel which require to be filled with sea water ballast after the fuel has been consumed need not all be examined internally provided that, after both the above external examination and testing and an internal examination of the after end of one forward tank, the Surveyor is satisfied with the condition.

208 All decks, casings and superstructures are to be examined. Attention is to be given to the corners of openings and other discontinuities in way of strength decks and top sides.

209 Wood decks or sheathing are to be examined; if decay or rot is found or the wood is excessively worn, the wood should be renewed. When a wood deck, laid on stringers and ties, originally required to be 75 mm (3 in) is worn to 65 mm (2·5 in), or 65 mm (2·5 in) to 50 mm (2 in), it is to be renewed.

Attention is to be given to the condition of the plating under wood decks, sheathing or other deck covering. If it is found that such coverings are broken or are not adhering closely to the plating, sections should be removed as necessary to ascertain the condition of the plating. (*See also* C 110).

210 The masts, standing rigging and anchors are to be examined. If the chain cables are ranged they should be examined. (*See* Table D 34.2 for renewals.)

The Surveyor should satisfy himself that there are sufficient mooring ropes on board and also that a tow line is provided when this is a Rule requirement.

211 The steering gear, and its connections and control systems (main and alternative) are to be examined. The various parts of the auxiliary steering gear are to be assembled and examined.

212 The windlass (*see* C 502), hand pumps, suctions, watertight doors, air and sounding pipes are to be examined. When examining tanks internally the Surveyor should see that striking plates are fitted under sounding pipes.

213 Where holds are insulated for the purpose of carrying refrigerated cargoes, and the hull in way of the insulation was examined by the Society's Surveyors at the time such insulation was fitted, it will be sufficient to remove the limbers and hatches to enable the framing and plating in way to be examined; in other cases additional insulation is to be removed as necessary to satisfy the Surveyor as to the condition of the structure. (*See also* N 8.)

214 The Surveyor is to satisfy himself as to the efficient condition of the following:—

Means of escape from (a) machinery spaces, (b) crew and passenger spaces, (c) spaces in which crew are normally employed.

Means of communication between (a) bridge and engine room, (b) bridge and alternative steering position.

Helm indicator, protection of aft steering wheel and gear.

215 For surveys of machinery, electrical equipment, boilers, steam pipes and screw shafts, *see* C 5 to C 11.

(B) At each Special Survey of ships between 5 and 10 years old.—The full requirements of 201 to 215 are to be complied with, together with the following:—

216 A sufficient amount of ceiling in the holds and in coal bunkers is to be removed from the bilges and inner bottom to enable the condition of structure in the bilges, the inner bottom plating, pillar feet, and the bottom plating of bulkheads and tunnel sides to be examined. If the Surveyor deems it necessary, the whole of the ceiling is to be removed.

217 In ships having a single bottom the limber boards and ceiling equal to not less than three strakes all fore and aft on each side are to be removed, one such strake being taken from the bilges. Where the ceiling is fitted in hatches, the whole of the hatches and at least one strake of ceiling in the bilges are to be removed. If the Surveyor deems it necessary the whole of the ceiling and limber boards are to be removed.

218 Tanks (excluding peak tanks) used exclusively for oil fuel or for oil fuel and fresh water ballast need not all be examined internally provided, from an external examination and testing and from an internal examination of the after end of one forward double bottom tank, and of one selected deep tank, the Surveyor is satisfied with the condition.

Lubricating oil tanks need not be examined internally.

219 The chain cables are to be ranged for inspection, and the anchors and chains examined. If any length of chain cable is found to be reduced in mean diameter at its most worn part to the extent indicated in Table D 34.2, it is to be renewed.

220 The chain locker is to be cleaned and examined internally.

(C) At each Special Survey of ships over 10 years old.—The full requirements of 201 to 220 are to be complied with, together with the following:—

221 The steel work is to be cleaned and the rust removed.

222 Casings of air, sounding, steam and other pipes, spar ceiling and lining in way of the sidescuttles are to be removed as required by the Surveyor.

223 If the Surveyor is satisfied after removal of portions of the ceiling in the holds, that the steel work is in good condition, free from rust, and coated, the removal of the whole may be dispensed with. In coal bunkers, however, the whole of the ceiling is to be removed.

224 Attention is to be given by the Surveyor to the inside of coal bunkers and the parts in way of the boilers.

225 Attention is also to be paid to the possibility of local wastage and grooving, e.g., at the shell plating along the heel of framing members.

226 All double bottom and other tanks are to be cleaned as necessary to permit their being examined internally, where this is required.

For ships of 10 and not more than 15 years old, tanks (excluding peak tanks) used exclusively for oil fuel, oil fuel and fresh water ballast, or lubricating oil need not all be examined internally provided, from an external examination and testing and from internal examination of one double bottom tank forward and one aft and one deep tank, the Surveyor is satisfied with the condition.

For ships of 15 and not more than 20 years old, tanks (excluding peak tanks) used exclusively for oil fuel, oil fuel and fresh water ballast or lubricating oil need not all be examined internally provided, from an external examination and testing and from an internal examination of at least one double bottom tank amidships, one forward and one aft and one deep tank, the Surveyor is satisfied with the condition. These tanks should be selected so that as many different tanks as possible are examined internally before the ship is 20 years old. For ships 20 years old or over, all tanks should be examined internally, but in those ships operating on a Continuous Survey basis and fitted with nested deep tanks comprising six or more adjoining tanks, such tanks need not all be examined internally provided that at each year of the survey cycle one selected tank from each nest is found from internal examination to be in good condition.

227 The cement chocks on the ship's sides at bilges and decks are to be examined, and portions removed, so that the condition of the shell plating and adjacent steel work can be ascertained. Portions of wood sheathing, or other covering, on steel decks are to be removed as considered necessary by the Surveyor in order to ascertain the condition of the plating.

228 Where the holds are insulated for the purpose of carrying refrigerated cargoes, the limbers and hatches are to be lifted, and sufficient insulation is to be removed in each of the chambers to enable the Surveyor to satisfy himself of the condition of the framing and plating. (*See also* N 8.)

229 All mast wedging is to be removed and renewed as necessary.

230 For ships of 15 and not more than 20 years old, in addition to the drilling required by 205 to ascertain local wastage, the shell plating between the light and load water lines and the strength deck plating outside the line of openings are to be gauged by drilling or other approved means to determine the amount of any general diminution in thickness. The gauging is to be done in at least two places in each strake of plating on each side within the midship half length.

(D) At the first Special Survey held after the ship is 20* years old and at every Special Survey thereafter—THE FULL REQUIREMENTS OF 201 TO 229 ARE TO BE COMPLIED WITH, TOGETHER WITH THE FOLLOWING:—

231 In addition to the drilling required by 205 to ascertain local wastage, the shell plating and plating of strength decks are to be gauged by drilling or other approved means to determine the amount of any general diminution in thickness. The gauging is to be done in at least two places in each strake of plating on each side within the midship half length. The remainder of the shell plating between the light and load water lines and the strength deck plating outside the line of openings, all within the midship half length, are also to be gauged.

All paint and rust is to be entirely removed before the plates are gauged by the Surveyor and the actual thicknesses are to be reported in detail to the Committee. Where drilled plates are renewed the thickness of adjacent plates in the same strake should be reported.

The thickness of bottom plating in way of cement is to be ascertained unless the Surveyor, after an internal and external examination, is entirely satisfied that this is unnecessary. Selected portions of the cement are to be removed from the bottom and bilge if required by the Surveyor.

* *For tankers see* C 307.

232 Where the holds are insulated for the purpose of carrying refrigerated cargoes, the limbers and hatches are to be lifted, and sufficient additional insulation is to be removed in each of the chambers to enable the Surveyor to satisfy himself of the condition of the steel structure, and to enable the thickness of the shell plating to be ascertained as required by 231.

Section 3

SPECIAL SURVEYS—TANKERS

Hull requirements additional to those stated in C 2.

Preparation and Inspection of Tanks

301 At all Special Surveys all cargo tanks and cofferdams are to be cleaned out, thoroughly cleared of gas, and examined. Every precaution is to be taken to ensure safety during inspection.

Attention is to be given to the inside of the bottom plating in order to ensure that there is no excessive pitting of the plating. When extensive pitting is found care should be taken to preserve the longitudinal strength of the bottom by the requisite renewals or repairs. In cases where cement has been laid in the bottom the Surveyor is to satisfy himself that there is no active corrosion under the cement.

302 The strums of the cargo suction pipes are to be removed to facilitate examination of the shell plating and bulkheads in that vicinity, unless other means for visual inspection of these parts are provided.

303 The attachment to the structure and condition of anodes in tanks is to be examined.

Testing

304 Each cargo tank bulkhead is to be tested at Special Surveys A and B by filling alternate tanks with water to the top of the hatchway. But at subsequent Special Surveys, or earlier if considered necessary by the Surveyor, all tanks are to be tested.

305 Tanks may be tested when the ship is afloat, provided the internal examination of the bottom is also carried out afloat.

306 Where extensive repairs have been effected to the shell plating, the tanks should be tested to the Surveyor's satisfaction.

Determination of Thickness

307 The requirements of 231 are to be complied with at every Special Survey after the ship is 10 years old except that, in respect of the deck plating, every deck plate within the midship half length is to be gauged. All gaugings are to be taken in way of tanks.

Section 4

LIQUEFIED GAS CARRIERS

Annual and Special Surveys—Requirements additional to those stated in C 1, C 2 and C 3.

Preparation before Survey

401 Prior to inspection of cargo tanks, cofferdams, associated piping, fittings or equipment, the respective items are to be cleaned and thoroughly cleared of gas. Every precaution is to be taken to ensure safety during inspection.

Annual Surveys

402 Where the maximum vapour pressure for which the cargo tanks have been approved as recorded in the Register Book is 0,7 kg/cm^2 (10 lb/in^2), or less, the inner surfaces of the tanks are to be examined annually.

Where submerged electrically driven pumps are fitted in the cargo tanks, the pumps, motors, control devices and interlocks are to be examined annually as required by 404.

Liquid level indicating devices, high level alarms, monitoring systems for revealing possible gas leakage and arrangements for inerting the tanks and containment spaces are to be examined and tested to ascertain that they are in good working order.

Special Surveys

403 At each Special Survey of the ship the tanks are to be examined internally, also externally so far as practicable, particular attention being paid to the plating in way of supports and securing arrangements, mountings and pipe connections, also to sealing arrangements at the deck.

Where the tanks are insulated, portions of the insulation are to be removed if required by the Surveyor to enable him to ascertain the condition of the plating.

Internal fittings are to be examined, all valves and cocks in direct communication with the interiors of the tanks are to be opened out for inspection and any pipes connecting them to the tanks are to be examined internally so far as practicable.

Liquid level indicating devices, high level alarms, monitoring systems for revealing possible gas leakage and arrangements for inerting the tanks and containment spaces are to be examined and tested to ascertain that they are in good working order.

Where provision is made for recording the temperature of the ship's structure adjacent to the tanks, the correct functioning of the apparatus, including audible alarms, is to be verified.

Pressure relief valves are to be opened out for inspection and subsequently adjusted to lift at a pressure not more than three per cent above the maximum vapour pressure for which the tanks have been approved. The valves may be removed from the tanks for the purpose of making this adjustment which may be effected under pressure of air or other suitable medium.

Vacuum relief valves are to be opened out, examined and tested to establish that they are in good working order.

Where the approved maximum vapour pressure of the cargo tanks is 0,7 kg/cm^2 (10 lb/in^2), or less, the tanks are to be tested by a head of water 2,45 m (8 ft) above the top of the tank or 610 mm (2 ft) above the top of the hatch, whichever is the greater. Where access to the outside of the cargo tanks is not possible other proposals for leak testing of the cargo tanks will be considered.

Where the approved maximum vapour pressure is above 0,7 kg/cm^2 (10 lb/in^2), the tanks are to be tested by pressure of water equal to one and a quarter times the approved maximum vapour pressure. Where these tanks are insulated, at the second Special Survey and at each alternate Special Survey thereafter, the insulation is to be removed in way of all supports and connections to the tanks prior to the water pressure test.

Where non-corrosive cargoes only are carried in uninsulated cylindrical tanks fitted in the ship with their longitudinal axes approximately vertical and the cargoes are not discharged by the admission of water to the tanks, proposals will be considered, upon application by the Owners, to omit the hydraulic test provided the tanks have been constructed in accordance with the Rules for Welded Pressure Vessels, Class 1, including stress relieving heat treatment, and the Surveyor is satisfied with their internal and external condition. Proposals to limit the amount of opening out of valves, cocks and pressure relief valves at each Special Survey will be considered provided all valves, etc., are seen in rotation in the course of each two consecutive Special Surveys.

Where insulation is attached to the hull structure, special consideration will be given to the necessity of removing it at Special Surveys but, in general, provided the Surveyor is satisfied that it is adhering properly and there are no traces of cold spots, this will not be required until the ship is at least eight years old. An examination of the wing tanks, double bottom tanks and transverse cofferdams, when the cargo tanks are loaded with liquefied gas at the minimum approved temperature, will be required at the Special Survey or at a convenient date immediately prior thereto.

404 Where submerged electrically driven pumps are fitted in the cargo tanks, at each Annual and each Special Survey the pumps and motors are to be withdrawn from the tanks and opened out for examination of the condition of the stator winding insulation, evidence of any damage due to thermal expansion and contraction and bearing wear. Any sludge deposits in the motor windings or casings are to be removed and insulation resistances, including those of the motors and supply cables, are to be measured before opening out and after refitting. The portions of supply cables within the cargo tanks and the cable glands are to be examined for signs of deterioration and/or gas leakage.

The control devices and interlocks actuated by pressure or liquid level in the tanks and master key switches, which cut off the supply of current to the motors, are to be checked under simulated working conditions and if necessary re-calibrated.

Where deep well pumps are fitted in the cargo tanks, at each Special Survey the control devices which cut off the supply of current to the motors are to be checked under simulated working conditions and if necessary re-calibrated.

405 Where refrigeration equipment is installed, either for maintaining the liquid cargo at the carrying temperature or for re-liquefying the "boil-off" and returning it to the tanks, Running and Special Surveys of the equipment are to be carried out in accordance with the requirements of Chapter N, so far as applicable.

In addition, at each Survey the ventilating fans and motors for the refrigerating machinery rooms are to be examined under working conditions and the operation of the temperature indicating equipment and the refrigerating plant checked by examination of the log records.

Section 5

GENERAL REQUIREMENTS—MACHINERY

APPLICABLE TO ALL SHIPS

At each Survey held in dry dock

501 When the ship is in dry dock the propeller, stern bush and sea connection fastenings and the gratings at the sea inlets are to be examined. The clearance in the stern bush or the efficiency of the oil gland should be ascertained.

Complete Surveys

502 At each Complete Survey required by B 807 the following parts are to be examined:—

SEA CONNECTIONS

While the ship is in dry dock all openings to the sea in the machinery spaces and pump rooms with the valves, cocks and the fastenings with which these are connected to the hull.

SHAFTING

All shafts (except screw and tube shafts for which special arrangements are detailed in C 11), thrust block and all bearings. The lower halves of bearings need not be exposed if alignment and wear are found acceptable.

REDUCTION GEARS, complete with all wheels, pinions, shafts, bearings and gear teeth.

AUXILIARY ENGINES, auxiliary air compressors with their intercoolers, filters and/or oil separators and safety devices, and all pumps and components used for essential services.

STEERING MACHINERY

WINDLASS

EVAPORATORS and their safety valves, which should be seen in operation under steam.

SECURING ARRANGEMENTS

The holding down bolts and chocks of main and auxiliary engines, gear cases, thrust blocks and tunnel bearings.

Air Receivers

All air receivers for essential services with their mountings, valves and safety devices are to be cleaned internally and examined internally and externally. If internal examination of the air receivers is not practicable, they are to be tested hydraulically to twice the working pressure.

Pumping Arrangements

The valves, cocks and strainers of the bilge system including bilge injection, are to be opened up as considered necessary by the Surveyor and, together with pipes, are to be examined and tested under working conditions. The oil fuel, feed and lubricating oil systems and the ballast connections and blanking arrangements to deep tanks which may carry liquid or dry cargoes, together with all pressure filters, heaters and coolers used for essential services, are to be opened up and examined or tested as considered necessary by the Surveyor. All safety devices for the foregoing items are to be examined.

Fuel Tanks and Fittings

Fuel tanks which do not form part of the ship's structure are to be examined and if considered necessary by the Surveyor they are to be tested to the pressure specified for new tanks. The tanks need not be examined internally at the first survey if they are found satisfactory on external inspection. All mountings, fittings and deck controls are to be examined so far as practicable.

Spare Gear

The spare gear is to be checked.

Remote and/or Automatic Controls

Where remote and/or automatic controls are fitted for essential machinery, they are to be tested to demonstrate that they are in good working order.

In addition to the above, detailed requirements for steam and oil engines, electrical installations and boilers are given in C 6, C 7, C 8 and C 9 respectively.

Section 6

STEAM ENGINES—DETAILED REQUIREMENTS

Complete Surveys

601 In addition to the requirements of C 5 the working parts of the main engines and attached pumps and of auxiliary machinery used for essential services including bulkhead stop valves, manœuvring valves, cylinders, pistons, valves and valve gear, piston rods, connecting rods, crossheads and guides, the crank shafts of reciprocating engines and the blading, rotors and casings of turbine machinery are to be opened up and examined.

Condensers, steam reheaters, desuperheaters which are not incorporated in the boilers and any other appliances used for essential services are to be examined to the satisfaction of the Surveyor, and if considered necessary they are to be tested.

The manœuvring of the engines is to be tested under working conditions.

602 Exhaust steam turbines supplying power for main propulsion purposes in conjunction with reciprocating engines are, together with their gearing and appliances, steam compressors or electrical machinery, to be examined so far as practicable. Where cone connections to internal gear shafts are fitted, the coned ends are to be examined so far as practicable.

603 In steam ships having essential auxiliary machinery driven by oil engines, the prime movers of these auxiliaries are to be examined as detailed in C 701.

Section 7

OIL ENGINES—DETAILED REQUIREMENTS

Complete Surveys

701 In addition to the requirements of C 5 the Complete Survey is to consist of the opening out and examination of the following parts: cylinders, covers, valves and valve gear, fuel pumps and fittings, scavenge pumps, scavenge blowers and their prime movers, superchargers, compressors, their intercoolers, filters and/or oil separators and safety devices, pistons, piston rods, crossheads, guides, connecting rods, crank shafts and all bearings, clutches, reverse gears, attached pumps, cooling system, crankcase door fastenings and explosion relief devices. Selected pipes in the starting air system are to be removed for internal examination and hammer-tested. If an appreciable amount of lubricating oil is found in the pipes, the starting air system is to be thoroughly cleaned internally by steaming or other suitable means. Some of the pipes selected are to be those adjacent to the starting air valves at the cylinders and to the discharges from the air compressors. The electric ignition system, if fitted, is to be examined and tested. The manœuvring of engines is to be tested under working conditions.

Where steam is used for essential purposes, the condensing plant, feed pumps, and oil fuel burning plant, are to be examined and the steam pipes examined and tested as detailed in C 10.

702 Gas turbines and free piston gas generators: in addition to the requirements of C 5, the Complete Survey is to consist of the opening and examination of the following parts: the blading, rotors and casings of the turbines, the impellers or blading, rotors and casings of the air compressors, the combustion chambers, burners, intercoolers, heat exchangers, gas and air pressure piping and fittings, starting and reversing arrangements.

Where gas turbines operate in conjunction with free piston gas generators, the following parts of the latter are to be opened and examined: the gas and air compressor cylinders and pistons and the compressor end covers, the valves and valve gear, fuel pumps and fittings, synchronising and control gear, cooling system, explosion relief devices, gas and air piping, receivers and valves including by-pass. The manœuvring of engines is to be tested under working conditions.

Section 8

ELECTRICAL EQUIPMENT

801 At each Complete Survey the electrical equipment is to be examined and tested in accordance with 802 to 811.

NOTE.—In cases where the Committee have consented to Continuous Surveys, the electrical equipment may also be included in the survey cycle. (*See* B 808.)

802 A test for insulation resistance is to be made on the cables, switchgear, generators, motors, heaters, lighting fittings, etc., and the insulation resistance is to be not less than 100 000 ohms between all insulated circuits and earth. The installation may be sub-divided to any desired extent by opening switches, removing fuses or disconnecting appliances for the purpose of this test.

803 The fittings on main and emergency switchboards, section boards and sub-distribution fuse boards are to be examined and over-current protective devices and fuses inspected to verify that they provide suitable protection for their respective circuits.

804 Generator circuit breakers are to be tested, so far as practicable, to verify that the protective devices including preference tripping relays, if fitted, operate satisfactorily.

805 The electric cables are to be examined so far as practicable without undue disturbance of fixtures or casings unless opening up is considered necessary as a result either of observation or of the tests required by 802.

806 The generator prime movers are to be surveyed as required by C 6 and C 7 and the governing of the engines tested. The motors concerned with essential services together with associated control and switch gear are to be examined and, if considered necessary, are to be operated so far as practicable under working conditions. All generators and steering gear motors are to be examined and are to be operated under working conditions, though not necessarily under full load or simultaneously.

807 Where transformers or electrical apparatus associated with supplies to essential services are oil-immersed, the Owners are to arrange for samples of oil to be taken and tested for breakdown voltage, acidity and moisture by a competent testing authority and a certificate giving the test results is to be furnished to the Surveyor.

808 Where electro-magnetic couplings are fitted, the air gaps to be measured and reported, and any excessive eccentricity corrected. The couplings and associated switchgear are to be examined and tested.

809 Navigation light indicators are to be tried under working conditions and correct operation on the failure of supply and failure of navigation lights verified.

810 In passenger ships the emergency source of power and its associated circuits and, where fitted, the temporary source of power and its automatic arrangements are to be tested. (*See* M 111.)

In cargo ships the emergency source of power and its associated circuits are to be tested. (*See* M 111.)

Electric Propelling Machinery

811 Where the ship is electrically propelled, the propulsion motors, generators, cables, and all ancillary electrical gear, exciters and ventilating plant (including coolers) associated therewith are to be examined and the insulation resistance to earth is to be tested. Special attention is to be given to windings, commutators and slip-rings. The operation of protective gear and alarm devices is to be checked so far as practicable. Insulating oil, if used, is to be tested in accordance with 807. Interlocks intended to prevent unsafe operations or unauthorised access are to be checked to verify that they are functioning correctly. Emergency overspeed governors are to be tested.

Section 9

BOILER SURVEYS

901 Water tube boilers supplying steam to the main propelling machinery (other than cylindrical boilers having corrugated or plain furnaces in conjunction with water tubes) and steam heated steam generators are to be surveyed at two-yearly intervals. All other boilers including domestic boilers having a working pressure exceeding 3,5 kg/cm^2 (50 lb/in^2) and a heating surface exceeding 4,65 m^2 (50 ft^2), also press boilers and similar apparatus in floating whale oil factories, and exhaust gas steam generators and economisers, are to be surveyed at two-yearly intervals until they are 8 years old and subsequently annually. In fired boilers employing forced circulation the pumps used for this service are to be opened and examined at each boiler survey.

902 At the surveys described in 901 the boilers, superheaters, economisers and air heaters are to be examined internally and externally, and where considered necessary the pressure parts are to be tested by hydraulic pressure and thickness of plates and tubes and size of stays are to be ascertained to determine a safe working pressure. The principal mountings on boilers, superheaters and economisers are to be opened up and examined and the safety valves adjusted under steam to a pressure not greater than 3 per cent above the approved working pressures of the respective parts. The remaining mountings are to be examined externally and are to be opened up for internal examination if considered necessary by the Surveyor. Collision chocks, rolling stays and boiler stools are to be examined and maintained in efficient condition.

903 The oil fuel burning system is to be examined under working conditions and a general examination made of fuel tank valves, pipes, deck control gear and oil discharge pipes between pumps and burners.

904 At each survey of a cylindrical boiler which is fitted with smoke tube superheaters, the saturated steam pipes are to be examined as detailed in C 1004.

Section 10

STEAM PIPES

Steel Pipes

1001 Incidence of Surveys.—Saturated steam pipes, also superheated steam pipes where the temperature of the steam at the superheater outlet is not over 454°C (850°F), are to be surveyed at the second and each subsequent Special Survey. Superheated steam pipes where the temperature of the steam at the superheater outlet is over 454°C (850°F) are to be surveyed at each Special Survey, including the first.

SCOPE OF SURVEYS

1002 PIPES HAVING BOLTED JOINTS.—At each survey a selected number of main steam pipes, also of auxiliary steam pipes over 75 mm (3 in) internal diameter supplying steam for essential services at sea, are to be removed for internal examination and hydraulically tested to twice the working pressure. If these selected pipes are found satisfactory in all respects, the remainder need not be tested. The pipes are, so far as practicable, to be selected for examination and hydraulic test in rotation so that in the course of surveys all sections of the pipeline will be tested.

1003 PIPES HAVING WELDED JOINTS.—Where main and/or auxiliary steam pipes of the category described in 1002 have welded joints between lengths of pipe and/or between pipes and valves, the lagging in way of the welds is to be removed, the welds examined and, if considered necessary by the Surveyor, crack detected. Plugs fitted in the piping for inspection purposes are to be removed and the piping examined internally as far as practicable by introscope or other optical means and, after the plugs have been replaced, the pipe lines are to be tested hydraulically to twice the working pressure. Where lengths having ordinary bolted joints are fitted in such pipe ranges and can be readily disconnected, they are to be removed for internal examination and hydraulically tested to twice the working pressure.

1004 CYLINDRICAL BOILERS HAVING SMOKE TUBE SUPERHEATERS.—Where the saturated steam pipes adjoining the saturated steam headers are situated partly in the boiler smoke boxes, all such pipes adjoining and cross-connecting these headers in the smoke boxes are, at the surveys required by 1001, to be included in the pipes selected for examination and testing as defined in 1002. Where the saturated steam pipes inside the smoke boxes consist of steel castings of substantial construction, these requirements need only be applied to a sample casting. Where steel castings are not fitted, the Surveyor is to satisfy himself of the condition of the ends of the saturated steam pipes in the smoke boxes *at each boiler survey* and, if he considers it necessary, a sample pipe is to be removed for examination.

1005 As an alternative to the requirements of 1002, and provided the saturated steam pipes in smoke boxes are dealt with as detailed in the first paragraph of 1004, the remainder of the pipes may, if the Owner wishes, be hydraulically tested in place to twice the working pressure. Lagging is to be removed as required by the Surveyor to permit effective examination.

Copper Pipes

1006 At the second and at each subsequent Special Survey all copper steam pipes over 75 mm (3 in) internal diameter supplying steam for essential services at sea are to be hydraulically tested to twice the working pressure. At these surveys any of the pipes which may be subject to bending and/or vibration, such as those having expansion or other bends, and closing lengths adjacent to steam driven machinery, are to be annealed before being tested.

Section 11

SCREW SHAFTS AND TUBE SHAFTS

1101 Screw shafts and tube shafts are to be drawn periodically for examination by the Society's Surveyors.

Where shafts are fitted with continuous liners or approved oil glands, or are made of approved corrosion resisting material, they normally become due for survey at intervals of 3 years for single screw ships and 4 years for ships having two or more screws. All other shafts should be drawn at intervals of 2 years.

1102 On the application of Owners, surveys of shafts of single screw ships having continuous liners or approved oil glands, or made of approved corrosion-resisting material may be held at intervals of 4 years, provided the keyway is of the sled-runner or round-ended type having adequate root radius, any sharp edge around the keyway at the surface of the shaft is removed by filing or other suitable means and, at each survey, the shaft is examined by an efficient crack detection method over a length from the after end of the liner (or after end of the stern tube for shafts not fitted with continuous liners) to a position at about one-third of the length of the cone from the large end. Upon application by the Owners and provided the keyway is as described above, a four-year period will also be allowed before the first survey of the shaft of a new single screw ship and may be allowed for a new or previously unused spare shaft fitted to an existing ship. At the first and subsequent periodical surveys the forward portion of the shaft cone is to be examined by an efficient crack detection method.

1103 The Committee will be prepared to give consideration to the circumstances of any special case upon application by the Owners.

Section 12

CLASSIFICATION OF SHIPS NOT BUILT UNDER SURVEY

1201 When classification is desired for a ship not built under the supervision of the Society's Surveyors, application should be made to the Committee in writing.

Hull and Equipment

1202 Plans showing the main scantlings and arrangements of the actual ship and any proposed alterations are to be submitted for approval. These should comprise midship section, longitudinal section and decks, and such other plans as may be requested. If plans cannot be obtained or prepared by Owners, facilities are to be given for the Society's Surveyor to take the necessary information from the ship.

Particulars of the process of manufacture and testing of the material of construction should be furnished.

1203 In all cases the full requirements of C 201 to C 230 are to be carried out. In the case of tankers the requirements of C 301 to C 306 are also to be carried out. Tankers over 10 years old are in addition to comply with C 307, and other ships over 20 years old with C 231 and C 232. During the survey the Surveyors are to satisfy themselves regarding the workmanship and verify the approved scantlings and arrangements. For this purpose, and in order to ascertain the amount of any deterioration, parts of the structure will require to be drilled as necessary. Full particulars of the anchors, chain cables and equipment are to be submitted. Fire protection, detection and extinction are to be in accordance with the Rules (*see* Chapter F). Ships of recent construction will receive special consideration.

1204 When the full survey requirements indicated above cannot be completed at one time, the Committee may consider granting an interim record for a limited period. The conditions regarding the completion of the survey will depend on the merits of each particular case, which should be submitted for consideration.

Machinery

1205 To facilitate the survey, plans of the following items, together with the particulars of the materials used in the construction of the boilers, air receivers and important forgings should be furnished:—

General pumping arrangements, including air and sounding pipes. (Shipbuilder's plan.)

Pumping arrangements at the forward and after ends of oil tankers and drainage of cofferdams and pump rooms.

General arrangement of cargo piping in tanks and on deck of oil tankers.

Piping arrangements for cargo oil (F.P. above 65,5°C (150°F)).

Bilge, ballast and oil fuel pumping arrangements in the machinery space, including the capacities of the pumps on bilge service.

Arrangement and dimensions of main steam pipes.

Arrangement of oil fuel pipes and fittings at settling and service tanks.

Arrangement of oil fuel piping in connection with oil burning installations.

Oil fuel and cargo oil overflow systems, where these are fitted.

Arrangement of boiler feed systems.

Oil fuel settling, service and other oil fuel tanks not forming part of the ship's structure.

Plans of piping are to be diagrammatic.

Boilers, superheaters and economisers.

Air receivers.

Crank, thrust, intermediate and screw shafting.

Clutch and reversing gear with methods of control.

Reduction gearing.

Electrical circuits.

NOTE.—Plans additional to the above should not be submitted unless the machinery is of a novel or special character affecting classification.

Where remote and/or automatic controls are fitted to propulsion machinery and essential auxiliaries, a description of the scheme is to be submitted. Particulars are to be given of the spare gear carried for machinery and control gear and whether maintenance is by repair or replacement.

TORSIONAL VIBRATION CHARACTERISTICS

For new ships and ships which have been in service less than 8 years calculations of the torsional vibration characteristics of the propelling machinery are to be submitted for consideration as required for ships constructed under Special Survey. For older ships the circumstances will be specially considered in relation to their service record and type of machinery installed.

Where calculations are not submitted the Committee may require that the machinery certificate be endorsed to this effect.

When desired by the Owners the calculations and investigation of torsional vibration characteristics of machinery may be carried out by the Society upon special request.

1206 The main and auxiliary machinery, also feed pipes, compressed air pipes and boilers are to be examined as required at Complete Surveys, and their working pressures are to be determined from their actual scantlings in accordance with the Rules.

The screw shaft is to be drawn and examined.

The steam pipes are to be examined and tested as required by C 10.

The bilge, ballast and oil fuel pumping arrangements are to be examined and amended as necessary to comply with the Rules.

Oil burning installations are to be examined as required at Complete Surveys and found, or amended, to comply with the requirements of the Rules; they are also to be tested under working conditions.

The electrical equipment is to be examined as required at Complete Surveys.

The spare gear is to be in accordance with the Rules.

The whole of the machinery, including essential controls, is to be tried under working conditions to the Surveyor's satisfaction.

First entry reports are to be prepared by the Surveyors.

1207 Where classification with the Society is desired for a ship which is classed by another recognised Society, special consideration will be given to the scope of the machinery survey.

Periodical Surveys

1208 Periodical surveys are subsequently to be held as in the case of ships built under survey.

19th March, 1970

NOTE

Chapter D of these Rules is applicable only to ships of 90 m (295 ft) and over in length. For vessels under 90 m (295 ft) in length, the 1967 Rules are to be used.

Chapter D

STEEL SHIPS

(*See Note on page* 29)

Section 1

GENERAL

Application

101 This Chapter applies to sea-going dry cargo ships of normal form and proportions of 90 m (295 ft) and over in length.

Ships of unusual form or proportions, or intended for the carriage of special cargoes, will receive individual consideration on the basis of the general standards of these Rules. (For the carriage of liquefied gases, *see* D 70, D 71 and D 72.)

The scantlings and arrangements in passenger ships will be specially considered in relation to the general design features.

For ships under 90 m (295 ft) in length and for tugs, dredgers and hopper barges the appropriate Sections of the 1967 Rules are to be applied.

102 Where the ratio of length to depth exceeds 16, increased longitudinal scantlings may be required (length and depth as defined in D 2).

Ballasting

103 Attention should be given to the amount and distribution of water ballast. It has been found that satisfactory service has been obtained when the draught forward is not less than 0,027L and the longitudinal radius of gyration of the ballasted ship is less than 0,25L.

Material

104 Mild steel is to comply with P 2. A grade higher than A is only required when specifically mentioned in this Chapter.

Where higher tensile steel complying with P 3 is used the scantlings may be reduced in accordance with D 65, D 66 and D 67.

105 Aluminium alloy used for superstructures, deckhouses, hatch covers or other structural members is to comply with P 12.

Method of Construction

106 The Rules apply to all welded construction.

Distribution of Continuous Longitudinal Material

107 The midship scantlings are to extend over 0,4L amidships and are to be reduced gradually to those permitted at the ends except as otherwise required by these Rules.

Equivalents

108 Alternative arrangements or fittings which are considered to be equivalent to the Rule requirements will be accepted.

Plans

109 Plans covering the following items are to be submitted:—

- Midship section.
- Longitudinal section.
- Shell plating (indicating extent of flat of bottom forward).
- Decks.
- Watertight bulkheads.
- Pillars and girders.
- Deep tanks.
- Oil fuel bunkers.
- Arrangement of fore body.
- Rudder.
- Sternframe.
- Propeller brackets.
- Main engine and thrust seating.
- Arrangement of after end.
- Superstructure and deckhouse.
- Hatchways.
- Strengthening for navigation in ice.
- Masts and derrick posts.
- Scheme of welding.
- Particulars for calculation of freeboard.
- Fire protection, detection and extinction arrangements.

The information required by D 302, D 303, D 304 and D 305 is to be submitted as may be necessary.

NOTE:—It is recommended that a plan be carried in the ship indicating the position and grades (other than Grade A) of hull structural steel and any recommendations for welding, working and treatment of such steels.

Corrosion Control

110 Where an approved system of corrosion control is provided in deep tanks, double bottom tanks, topside tanks, hopper side tanks, side ballast tanks, peak tanks or oil fuel bunkers, the reductions in thickness given in Table D 1.1 will be allowed.

If cathodic protection is adopted for water ballast tanks and reductions are desired at the top of a deep tank within 1,5 m (5·0 ft) of the deckhead, then this part of the tank is to be coated.

Where reductions are desired, full particulars of the protection proposed are to be submitted and the plans are to show both the Rule and reduced scantlings. An appropriate notation may be made in the Register Book.

TABLE D 1.1

Item	Permissible reduction in thickness
All structural items wholly within the protected tank with the exception of longitudinals on the bottom, side, strength deck, and on other longitudinal strength members.	10%
Items of which one side only is within the protected tank, e.g., transverse bulkhead at end of deep tank, tank top plating, etc. (*see* Note 1). Longitudinals on the bottom, side, deck and on other longitudinal strength members. Keel (*see* Note 2). Bottom shell (*see* Note 2). Side shell (*see* Note 2). Deck plating (*see* Note 2).	5%

NOTES:—1. The tank top, and lower strakes of longitudinal and transverse bulkheads where liable to suffer grab or bulldozer damage only to be reduced by 5 per cent even if protected on both sides.

2. Reduction not affected by means of external protection.

Modulus of Stiffeners, Girders, etc.

111 For longitudinals, side frames and bulkhead stiffeners the Rule section modulus required by the appropriate formula is that of the section in association with 610 mm (24 in) of plating having the same thickness as the shell, deck or bulkhead plating as appropriate. Where the attached plating is of varying thickness, the mean thickness over the span is to be used.

The effective section moduli of rolled sections and the area of the section without plating are given in the publication "Geometric Properties of Rolled Sections and Built Girders".

The effective section moduli of flat bars or built sections may be obtained from curves in the above publication.

112 For girders (including weather deck hatch side coamings), transverses, webs, etc., the Rule section modulus required by the appropriate formula is that of the member in association with an effective area of attached plating as given in D 5304, unless otherwise specified.

Section 2

DEFINITIONS

201 Length L is the distance, in metres (feet), on the summer load waterline from the fore side of the stem to the after side of rudder post, or to the centre of the rudder stock if there is no rudder post. L is not to be less than 96 per cent, and need not be greater than 97 per cent, of the extreme length on the summer load waterline.

Amidships is to be taken as the middle of the length L measuring from the fore side of the stem.

In ships with unusual stern arrangement the length L will be specially considered.

202 Breadth B is the greatest moulded breadth, in metres (feet).

203 Depth D is measured, in metres (feet), at the middle of the length L from top of keel to top of the deck beam at side on the uppermost continuous deck or as defined in appropriate Sections.

When a rounded gunwale is arranged the depth D is to be measured to the continuation of the moulded deck line.

204 Draught d is the summer draught, in metres (feet), measured from top of keel.

205 Passenger ship is a ship, engaged on international voyages, which carries more than twelve passengers.

206 Other parameters are defined in the appropriate Sections.

Section 3

LONGITUDINAL STRENGTH

301 The section modulus at deck and keel is not to be less than the greatest of the following values:—

(a) M cm³

(b) $\frac{M}{3} + 92\,SWBM_L\ (C_b + 0{,}20)$ cm³

(c) $\frac{0{,}85M_1}{3f} + 92\,SWBM_B\,(C_{b1}+0{,}20)$ cm³

where $M = f\,K\,B\,(C_b + 0{,}70) \times 10^5$

$M_1 = f\,K\,B\,(C_{b1} + 0{,}70)\times 10^5$,

f = 0,85 for the class 100A1 or 100A1 "Strengthened for Heavy Cargoes",
0,90 for the class 100A1 "Strengthened for Heavy Cargoes—Specified holds may be empty".

or in British units:—

(a) M in²ft

(b) $\frac{M}{3} + \frac{SWBM_L\,(C_b + 0{\cdot}20)}{6{\cdot}9}$ in²ft

(c) $\frac{0{\cdot}85\,M_1}{3f} + \frac{SWBM_B\,(C_{b1} + 0{\cdot}20)}{6{\cdot}9}$ in²ft

where $M = f\,K\,B\,(C_b + 0{\cdot}70) \times 10^3$

$M_1 = f\,K\,B\,(C_{b1} + 0{\cdot}70)\times 10^3$,

f = 0·85 for the class 100A1 or 100A1 "Strengthened for Heavy Cargoes",
0·90 for the class 100A1 "Strengthened for Heavy Cargoes—Specified holds may be empty".

(*See* D 3A for Carriage of Ore Cargoes—For these Rules, a stowage rate of 0,70 m³/tonne (25 ft³/ton), based on the cubic capacity, excluding hatchways, of the holds concerned is taken as the demarcation between "Ore Cargoes" and "Heavy Cargoes".)

K is to be determined from Table D 3.1,

C_b = the moulded block coefficient at load draught or 0,045L, whichever is the greater, but is not to be taken as less than 0,60. The block coefficient is to be determined using the length L as defined in D 201,

C_{b1} = the moulded block coefficient at the ballast or part loaded draught but is not to be taken as less than 0,60. The block coefficient is to be determined using the length L as defined in D 201. (*See* also D 103),

B = the moulded breadth, in metres (feet),

$SWBM_L$ = the maximum still water bending moment, in tonnes metres (tons feet), hogging or sagging in loaded conditions (*see* 302 to 305),

$SWBM_B$ = the maximum still water bending moment, in tonnes metres (tons feet), hogging or sagging in ballast or part loaded conditions (*see* 302 to 305).

NOTE:—When the required modulus is M, the maximum permissible still water bending moment in loaded conditions will be

$$\frac{7{,}25\,M}{C_b + 0{,}20} \times 10^{-3}\ \text{tonne m} \quad \left(\frac{4{\cdot}6\,M}{C_b + 0{\cdot}20}\ \text{ton ft}\right)$$

which corresponds to a stress of

$$\frac{7{,}25}{C_b + 0{,}20}\ \text{kg/mm}^2 \quad \left(\frac{4{\cdot}6}{C_b + 0{\cdot}20}\ \text{ton/in}^2\right)$$

302 The still water bending moment calculation for homogeneous and, if applicable, non-homogeneous load conditions and for the ballast or part loaded conditions (departure and arrival) is to be submitted.

303 When a class notation is desired permitting certain holds to be empty, curves of still water bending moment and shear force are to be submitted. These may also be required when unusual loading conditions are proposed.

304 The method of calculating the still water bending moment and shear force curves (where applicable) is to be submitted for approval. The assumed longitudinal distribution of lightship weight is also to be submitted.

305 When the still water bending moment is required to be calculated for conditions other than homogeneous load conditions, the approved loading is to be incorporated in the Loading Manual.

The Loading Manual is to be submitted for approval of the longitudinal distribution of cargo and ballast as shown therein.

306 In order to guard against high stresses being imposed through an unsatisfactory cargo or ballast loading, it is recommended that an approved means of determining the suitability of loading be placed on board.

TABLE D 3.1—VALUES OF K

LENGTH L	K	Difference in K per 1 m difference in L	LENGTH L	K	Difference in K per 1 m difference in L	LENGTH L	K	Difference in K per 1 m difference in L
Metres			Metres		0,0396	Metres		0,0670
90	0,747	0,0236	**165**	2,950	0,0414	**240**	7,025	0,0688
95	0,865	0,0240	**170**	3,157	0,0430	**245**	7,369	0,0706
100	0,985	0,0242	**175**	3,372	0,0448	**250**	7,722	0,0722
105	1,106	0,0244	**180**	3,596	0,0468	**255**	8,083	0,0730
110	1,228	0,0246	**185**	3,830	0,0488	**260**	8,448	0,0736
115	1,351	0,0250	**190**	4,074	0,0510	**265**	8,816	0,0740
120	1,476	0,0260	**195**	4,329	0,0530	**270**	9,186	0,0744
125	1,606	0,0276	**200**	4,594	0,0548	**275**	9,558	0,0746
130	1,744	0,0294	**205**	4,868	0,0564	**280**	9,931	0,0748
135	1,891	0,0310	**210**	5,150	0,0580	**285**	10,305	0,0750
140	2,046	0,0328	**215**	5,440	0,0598	**290**	10,680	0,0754
145	2,210	0,0344	**220**	5,739	0,0616	**295**	11,057	0,0760
150	2,382	0,0362	**225**	6,047	0,0634	**300**	11,437	0,0770
155	2,563	0,0378	**230**	6,364	0,0652	**305**	11,822	
160	2,752	0,0396	**235**	6,690	0,0670			

307 All continuous longitudinal material is to be included in the calculation of the inertia of the section, and the lever y is to be measured from the neutral axis to the top of keel and to the moulded deck line at side. Lightening holes in girders need not be deducted, provided their depth does not exceed 20 per cent of the depth of the girder web. Scallops and isolated drain holes need not be deducted.

In general, isolated deck openings outside the line of hatches need not be deducted, but local compensation may be required—*see* D 407.

308 Where continuous hatch coamings are arranged, 80 per cent of the area of the continuous hatch coamings may be included in the calculation of the section modulus and the lever y is to be measured:—

(a) to the moulded deck line at side amidships,

(b) to a point a distance above the moulded deck line at side amidships equal to the height of the hatch coaming above the deck.

The modulus with y measured as in (a) is to be 5 per cent greater than required by 301, and with y measured as in (b) may be 10 per cent less than required by 301.

309 Where two or more hatchways are arranged abreast, the percentage of the material between hatchways to be included in the section modulus will be decided in each case. Similar consideration will be given to other special designs.

310 When an erection is fitted the required modulus is to be determined in accordance with D 16. The required upper deck area clear of the erection is to extend to at least a distance equal to 0,04L inside the erection at each end.

or in British units:—

TABLE D 3.1—VALUES OF K

LENGTH L	K	Difference in K per 1 ft difference in L	LENGTH L	K	Difference in K per 1 ft difference in L	LENGTH L	K	Difference in K per 1 ft difference in L
Feet			Feet		0·0019	Feet		0·0031
300	0·121	0·0011	540	0·456	0·0020	780	1·067	0·0032
310	0·132	0·0011	550	0·476	0·0020	790	1·099	0·0032
320	0·143	0·0011	560	0·496	0·0020	800	1·131	0·0033
330	0·154	0·0011	570	0·516	0·0021	810	1·164	0·0033
340	0·165	0·0012	580	0·537	0·0021	820	1·197	0·0034
350	0·177	0·0012	590	0·558	0·0022	830	1·231	0·0034
360	0·189	0·0012	600	0·580	0·0022	840	1·265	0·0034
370	0·201	0·0012	610	0·602	0·0023	850	1·299	0·0035
380	0·213	0·0012	620	0·625	0·0023	860	1·334	0·0035
390	0·225	0·0012	630	0·648	0·0024	870	1·369	0·0035
400	0·237	0·0012	640	0·672	0·0025	880	1·404	0·0035
410	0·249	0·0013	650	0·697	0·0026	890	1·439	0·0035
420	0·262	0·0013	660	0·723	0·0026	900	1·474	0·0035
430	0·275	0·0014	670	0·749	0·0027	910	1·509	0·0035
440	0·289	0·0014	680	0·776	0·0027	920	1·544	0·0035
450	0·303	0·0015	690	0·803	0·0028	930	1·579	0·0035
460	0·318	0·0016	700	0·831	0·0028	940	1·614	0·0035
470	0·334	0·0016	710	0·859	0·0028	950	1·649	0·0036
480	0·350	0·0016	720	0·887	0·0029	960	1·685	0·0036
490	0·366	0·0017	730	0·916	0·0029	970	1·721	0·0036
500	0·383	0·0017	740	0·945	0·0030	980	1·757	0·0036
510	0·400	0·0018	750	0·975	0·0030	990	1·793	0·0037
520	0·418	0·0019	760	1·005	0·0031	1000	1·830	
530	0·437	0·0019	770	1·036	0·0031			

Section 3A

CARRIAGE OF ORE CARGOES

Longitudinal Strength

1 The following requirements are applicable to the Class 100A1 ore carrier, or for the notations "Strengthened for Ore Cargoes", "Strengthened for Ore Cargoes—Specified holds may be empty" and "Strengthened for Ore Cargoes—Specified holds may be empty, or Oil Cargoes".

2 The section modulus at deck and keel is not to be less than the greatest of the following values:—

(a) M_O cm³

(b) $\dfrac{M_O}{3} + 104\ SWBM_L$ cm³

(c) $\dfrac{0{,}85\ M_1}{2{,}7} + 92\ SWBM_B\,(C_{b1} + 0{,}20)$ cm³

where $M_O = 0{,}90\ K\ B\ (C_b + 0{,}70) \times 10^5$,

$M_1 = 0{,}90\ K\ B\ (C_{b1} + 0{,}70) \times 10^5$,

K is to be determined from Table D 3.1,

C_b = the moulded block coefficient at load draught or 0,045L, whichever is the greater, but is not to be taken as less than 0,60. The block coefficient is to be determined using the length L as defined in D 201,

C_{b1} = the moulded block coefficient at the ballast or part loaded draught but is not to be taken as less than 0,60. The block coefficient is to be determined using the length L as defined in D 201. (*See also* D 103),

B = the moulded breadth, in metres,

$SWBM_L$ = the maximum still water bending moment, in tonnes metres, hogging or sagging in loaded conditions,

$SWBM_B$ = the maximum still water bending moment, in tonnes metres, hogging or sagging in ballast or part loaded conditions (departure and arrival).

or in British units:—

(a) M_O in²ft

(b) $\dfrac{M_O}{3} + \dfrac{SWBM_L}{6 \cdot 1}$ in²ft

(c) $\dfrac{0 \cdot 85\ M_1}{2 \cdot 7} + \dfrac{SWBM_B\,(C_{b1} + 0 \cdot 20)}{6 \cdot 9}$ in²ft

where $M_O = 0 \cdot 90\ K\ B\ (C_b + 0 \cdot 70) \times 10^3$

$M_1 = 0 \cdot 90\ K\ B\ (C_{b1} + 0 \cdot 70) \times 10^3$,

K is to be determined from Table D 3.1,

C_b = the moulded block coefficient at load draught or 0·045L, whichever is the greater, but is not to be taken as less than 0·60. The block coefficient is to be determined using the length L as defined in D 201,

C_{b1} = the moulded block coefficient at the ballast or part loaded draught but is not to be taken as less than 0·60. The block coefficient is to be determined using the length L as defined in D 201. (*See also* D 103),

B = the moulded breadth, in feet,

$SWBM_L$ = the maximum still water bending moment, in tons feet, hogging or sagging in loaded conditions,

$SWBM_B$ = the maximum still water bending moment, in tons feet, hogging or sagging in ballast or part loaded conditions (departure and arrival).

NOTE.—When the required modulus is M_O, the maximum associated still water bending moment in loaded conditions will be:—

$6{,}4\ M_O \times 10^{-3}$ tonne m ($4 \cdot 08\ M_O$ ton ft) which corresponds to a stress of 6,4 kg/mm² (4·08 ton/in²).

Section 4

DECK PLATING

Symbols

401 L = length of ship, in metres (feet).

L_1 = length of ship, in metres (feet), but need not be taken as greater than 215 m (705 ft).

s = spacing of beams or longitudinals, in mm (in).

Construction

402 Provision is made for longitudinal or transverse framing at all decks, but for ships exceeding 120 m (395 ft) in length, longitudinal framing is, in general, to be adopted at the strength deck.

STRENGTH DECK

403 The thickness of strength deck plating amidships outside the line of openings is to be that necessary to give the section modulus required by D 3 or D 3A, but it is not to be less than:—

(a) Longitudinal framing $\frac{S}{100}\left(1+\frac{L}{305}\right)$ mm

(b) Transverse framing $\frac{S}{90}\left(1+\frac{L}{305}\right)$ mm

(S is not to be taken as less than $\frac{L_1}{0,6}+510$ mm except when the actual spacing is considerably less than this value).

Inside the line of openings, the thickness amidships is not to be less than:—

(c) Longitudinal or transverse framing $6{,}5+\frac{L}{48}$ mm

for a spacing not exceeding $\frac{L_1}{0,6}+650$ mm

or in British units:—

(a) Longitudinal framing $\frac{S}{100}\left(1+\frac{L}{1000}\right)$ in

(b) Transverse framing $\frac{S}{90}\left(1+\frac{L}{1000}\right)$ in

(S is not to be taken as less than $\frac{L_1}{50}+20$ in except when the actual spacing is considerably less than this value).

Inside the line of openings, the thickness amidships is not to be less than:—

(c) Longitudinal or transverse framing $0{\cdot}255+\frac{L}{4000}$ in for a spacing not exceeding $\frac{L_1}{50}+25{\cdot}5$ in.

For grades of steel, *see* 410.

The midship thickness outside line of openings is to be maintained for 0,4L amidships and is to be tapered gradually to the end thickness.

End Thickness

404 The thickness of deck plating for 0,1L from the ends is not to be less than $6+\frac{L}{48}$mm $\left(0{\cdot}235+\frac{L}{4000}\text{ in}\right)$.

Superstructures

405 When an erection is fitted amidships, the required strength deck plating thickness clear of the erection should extend within the erection as required by D 310. The plating thickness within the erection is to be determined as follows:—

(a) If erection efficiency factor (*see* D 16) = 0 then the thickness should be derived from 403.

(b) If erection efficiency factor = 1,0 then the thickness should be derived from 412 for second, third or platform deck as appropriate to the number of erection decks above.

(c) For intermediate values of erection efficiency factor, the minimum thickness should be obtained by interpolation.

406 For increases to thickness of deck plating in way of ends of superstructures, *see* D 1715.

Deck Openings

407 Openings in the strength deck outside line of openings should be kept to a minimum and are to be arranged clear of main hatch corners.

Openings in the strength deck forward of a midship bridge between hatch and bridge front and adjacent to a hatch corner are to be avoided so far as possible. If they are essential, special consideration is to be paid to their design and grade E steel may be required in these regions.

Compensation is not required for elliptical or circular deck openings in the strength deck situated within 0,5L amidships when the breadth of opening does not exceed 10 per cent of the distance between the hatch side and the ship's side, but:—

(a) Elliptical openings are to have the major axis fore and aft and the ratio of length to breadth of the opening is not to be less than 2:1.

(b) Circular openings are to be reinforced as required by 408.

Where elliptical or circular openings in strength deck and within 0,5L amidships have a breadth greater than that given above, compensation is to be provided for the excess breadth of opening. The compensating area is normally to be provided by increasing the deck thickness. In addition, circular openings are to be reinforced as required by 408.

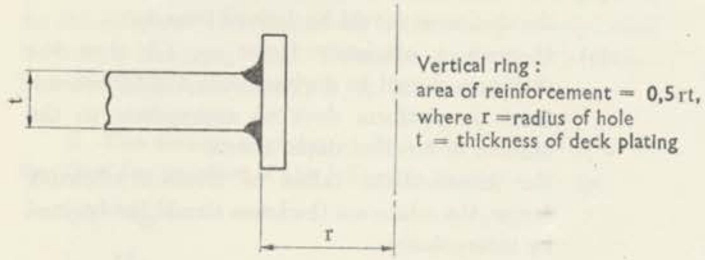
Full compensation is to be provided for openings of other shapes within 0,5L amidships.

Outside 0,5L amidships compensation is not, in general, required except for openings at the break of a poop.

The above requirements also apply generally to openings in lower decks but the breadth before compensation is required may be 15 per cent and edge reinforcement to circular openings is not required where their breadth does

not exceed 10 per cent of the distance between the hatch side and the ship's side.

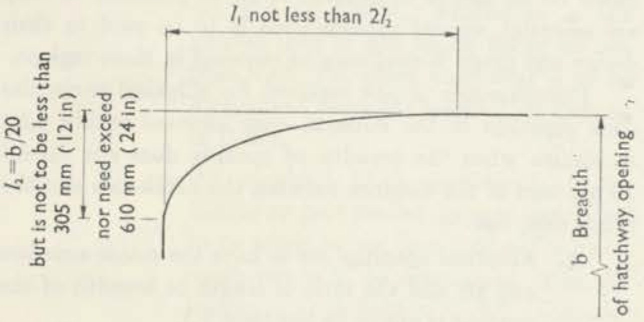
408 Where circular holes in the strength deck are required to be reinforced (*see* 407), this is generally to be arranged as shown but alternative arrangements for edge reinforcement will be considered.



409 Where the corners of large openings in the strength deck are parabolic or elliptic, insert plates are not required.

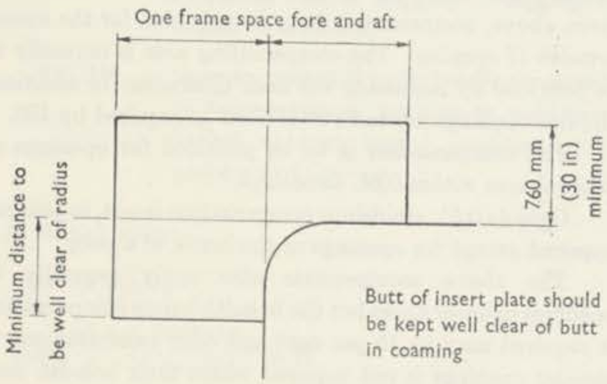
If elliptical corners are arranged, the major axis should be fore and aft, the ratio of the major to minor axis should not be less than 2:1, and the minimum half length of the major axis is to be as defined by l_1 in sketch below.

Where parabolic corners are arranged, the dimensions should be as shown in the following sketch:—



Where two or more hatchways are arranged abreast, the corner arrangements will be considered.

For other shapes of corner, insert plates of the following size and extent will be required:—



Required thickness of insert plate:—

Thickness of insert is to be 5 mm (0·20 in) greater than deck thickness up to deck thickness of 25,5 mm (1·00 in). At a deck thickness of 38 mm (1·50 in) and above the increase is to be 4 mm (0·15 in). Between 25,5 and 38 mm (1·00 and 1·50 in), the increase is to be obtained by interpolation.

See also 419.

Grades of Steel

410 Steel of Grade D will generally be required for the strength deck as follows:—

(a) where the thickness of plating exceeds 20,5 mm (0·80 in):—

(i) from 0,2L aft of amidships to 0,2L forward of amidships,

(ii) at corners of openings and at breaks of superstructures irrespective of position,

(b) any stringer plating outside 0,4L amidships when the thickness exceeds 25,5 mm (1·00 in).

See also 422 for refrigerated ships.

See also D 1917 for topside tanks.

411 Any deck plate at a hatch corner exceeding 35,5 mm (1·40 in) in thickness is to be Grade E.

LOWER DECKS

412 The thickness of plating is not to be less than that given below:—

Second deck—outside line of openings and within 0,4L amidships ...	$\frac{S}{85}$ mm (in)
Second deck—within line of openings and for 0,1L at ends	$\frac{S}{100}$ " "
Third deck—outside line of openings and within 0,4L amidships ...	$\frac{S}{95}$ " "
Third deck—within line of openings and for 0,1L at ends	$\frac{S}{100}$ " "
Platform decks	$\frac{S}{100}$ " "

The value of S for use in the above formulæ is not to be taken as less than $\frac{L_1}{0,6} + 510$ mm $\left(\frac{L_1}{50} + 20\,\text{in}\right)$.

Consideration will be given when the actual spacing is considerably less than this value.

Where a deck loading exceeding 4,4 tonne/m^2 (0·4 ton/ft^2) is contemplated, the thickness of the deck plating will be considered.

413 Where long wide hatchways are arranged on lower decks, it may be necessary to increase the deck thickness obtained from 412 to ensure effective support for side framing.

414 Deck plating forming the upper flange of underdeck girders is to have a thickness in mm (in) not less than:—

$$\sqrt{\frac{\text{girder face area (cm}^2\text{)}}{1{,}8}} \qquad \left(\sqrt{\frac{\text{girder face area (in}^2\text{)}}{180}}\right)$$

and 10 per cent greater than this for hatch side girders. The width of the increased plate is not to be less than 760 mm (30 in).

415 The arrangements at hatch corners in second decks are to be in accordance with 409 except that the thickness of the insert (if required) may be 2,5 mm (0·10 in) greater than the deck thickness.

416 For grades of steel in refrigerated ships, *see* 422.

GENERAL

Deck Loading

417 For permissible deck loading appropriate to rule scantlings and for scantlings for specific loading, *see* D 25.

See also 425 and 426.

Fork Lift Trucks

418 If provision is to be made for the use of fork lift trucks, it is recommended that the deck thickness should not be less than that given in Table D 4.1.

If fork lift trucks are to be used on insulated decks or tank tops, consideration will be given to the permissible loading in association with the insulation arrangements and the plating thickness.

Structural Details

419 Attention is to be paid to structural continuity. Abrupt changes of shape or section and sharp corners are to be avoided. The plating at corners of all openings in strength decks is to be well rounded and free from notches. (*See also* 407 and 409.)

Where the deck is connected to the main hatchway coamings by welding, the deck opening and the coamings at the corners of the hatchways are to be rounded with a radius which, for openings within 0,3L forward and aft of amidships, is not to be less than $\frac{1}{24}$ of the breadth of the opening; the minimum radius at all main hatchways in the strength deck is to be 150 mm (6 in).

If the deck plating extends inside the coamings the arrangements may be as in the preceding sub-paragraph, or the coamings may be square at the corners, provided that:—

(a) within 0,3L forward and aft of amidships, the side coamings are extended in the form of a tapered bracket, and,

(b) the openings in the deck plating at the corners are elliptic or parabolic, or are rounded with a radius which, for openings within 0,3L forward and aft of amidships, is not to be less than $\frac{1}{24}$ of the breadth of the opening with a minimum of 305 mm (12 in), and for openings forward or abaft this region is to be a minimum of 150 mm (6 in).

TABLE SD 4.1

Type of Truck	Total Weight of Truck and Load Tonnes/Tons											
	3	4	5	6	7	8	9	10	11	12	13	14
	Minimum Deck Thickness (irrespective of beam or longitudinal spacing) mm (in)											
Two Wheels at Fork End	7,5 (0·30)	9,0 (0·35)	10,0 (0·40)	11,0 (0·44)	12,0 (0·47)	12,5 (0·50)	13,5 (0·53)	14,0 (0·55)	15,0 (0·59)	15,5 (0·61)	16,0 (0·63)	16,5 (0·65)
Four Wheels in pairs at Fork End ...	6,5 (0·26)	7,5 (0·30)	8,0 (0·32)	9,0 (0·35)	9,5 (0·38)	10,5 (0·41)	11,0 (0·44)	11,5 (0·46)	12,0 (0·47)	12,5 (0·50)	13,0 (0·51)	13,5 (0·53)

Where the deck plating stops at the coaming and is welded thereto, through penetration welds are to be used. Where the deck plating extends inside the coaming, the free edges of the plating in way of the hatchways are to be smooth and free of weld attachments.

Arrangements at the welded corners of machinery casings will be considered.

Sheathed Decks

420 Where plated decks are sheathed with wood or approved composition, the minimum thicknesses given in 403, 404 and 412 may be reduced by 10 per cent for a 50 mm (2 in) sheathing thickness or 5 per cent for 25,5 mm (1 in), with intermediate values in proportion.

The steel deck is to be coated with a suitable material in order to prevent corrosive action and the sheathing or composition is to be effectively secured to the deck. (*See also* F 807 and F 1003.)

Water Testing

421 Weather decks, where riveted, are to be caulked and hose tested on completion.

Refrigerated Ships

422 If the temperature of the steel of the deck can fall to the values given in Table D 4.2 the grade of steel for the following items shall comply with the requirements of the table:—

Deck plating, webs of deck girders,
Longitudinal bulkhead strakes attached to the deck,
Hatch coaming shelf plates and their face bars.

Consideration will be given to cases where the width of affected material is considerably less than the width of the hatchways.

423 For the purposes of 422, the temperature to which the steel deck may be reduced is to be assessed as follows:—

Arrangement	*Deck Temperature*
1. Deck not covered with insulation in the refrigerated space.	Temperature of the refrigerated space.
2. Deck covered with insulation in the refrigerated space and not insulated on the other side.	Temperature of the space on the uninsulated side.
3. Deck covered with insulation on both sides.	(a) Mean of the temperatures of the spaces above and below the deck provided the difference in the temperatures is not more than 11 degC (20 degF). (b) Mean of the temperatures of the spaces above and below the deck less 3 degC (5 degF) if the difference in the temperature is more than 11 degC (20 degF) but not more than 33 degC (60 degF). (c) When the temperature difference is more than 33 degC (60 degF) the deck temperature will be specially assessed.

When one of the spaces concerned is not refrigerated, the temperature of that space is to be taken as 5°C (41°F).

Deep Tank

424 For minimum thickness of plating of a deck forming the crown of tank, *see* D 1919.

Carriage of Timber on Strength Deck

425 Ships to which a timber load line is assigned are to be specially strengthened (*see* D 808 and D 1319) and Owners are referred to the Load Line Convention for the permissible height of timber deck cargo.

Concentrated Loading

426 Additional strengthening to the decks may be required where there is indication of concentration of loading.

Higher Tensile Steel

427 When higher tensile steel is used, the scantlings are to be determined in accordance with D 65, D 66 and D 67.

428 When higher tensile steel is used amidships and mild steel at the ends, the taper line for the mild steel is to be determined using a nominal mild steel midship thickness of:—

(a) higher tensile thickness/k or,
if the higher tensile steel thickness is based upon minimum thickness requirements:—

(b) the minimum mild steel thickness determined from 403.

The higher tensile steel thickness, outside the midship 0,4L, is to be based upon a taper line from the midship thickness at 0,2L aft or forward of amidships to any point on the mild steel taper line.

TABLE D 4.2

TEMPERATURE	GRADE OF STEEL	
	STRENGTH DECK WITHIN 0,5L AMIDSHIPS	STRENGTH DECK AT ENDS AND SECOND AND LOWER DECKS
Below 0°C (32°F) but not below −5°C (23°F)	D	D
Below −5°C (23°F) but not below −10°C (14°F)	E	D
Below −10°C (14°F) but not below −20°C (−4°F)	E	Steel conforming to the test requirements of Grade D at −10°C (14°F)
Below −20°C (−4°F)	Steel conforming to the test requirements of Grade E at the temperature concerned	Steel conforming to the test requirements of Grade D at the temperature concerned

Section 5

SHELL PLATING

Symbols

501 L = length of ship, in metres (feet).

L_1 = length of ship, in metres (feet), but need not be taken as greater than 215 m (705 ft).

D = moulded depth, in metres (feet), to the uppermost continuous deck. In way of a superstructure not less than 0,15L in length, D may be taken to the superstructure deck.

B = moulded breadth, in metres (feet).

d = moulded draught, in metres (feet), but need not be taken as greater than:—

$\frac{L}{15}$ when L does not exceed 135 m (443 ft),

$\frac{L}{30} + 4{,}5$ when L exceeds 135 m

$\left(\frac{L}{30} + 14{\cdot}77 \text{ when L exceeds 443 ft}\right)$

s = spacing of frames or longitudinals, in mm (in).

S = spacing of floors or transverses, in metres (feet).

General

502 Provision is made for longitudinal or transverse framing for the bottom and side shell, but for ships exceeding 120 m (395 ft) in length, longitudinal framing is, in general, to be adopted at the bottom.

Keel

503 The width and thickness of the keel over the whole length are not to be less than the values derived from the following formulæ, nor is the thickness to be less than that of the adjacent shell plating.

Width = 70B mm (0·84B in) but need not exceed 1800 mm (71 in)

$$\text{Thickness} = 6 + \frac{L_1}{10}\text{ mm} \quad \left(0{\cdot}235 + \frac{12L_1}{10\,000}\text{ in}\right)$$

For grades of steel, *see* 512 and 513.

Bottom Shell

504 The thickness of bottom shell plating amidships to the upper turn of bilge is to be that necessary to give the section modulus required by D 3 or D 3A, but is not to be less than:—

(a) Longitudinal framing ... $\frac{s}{3000}(L_1 + 75)\sqrt{\frac{d}{L_1}}$ mm

(b) Transverse framing ... $\frac{s}{3000}(L + 165)\sqrt{\frac{d}{L}}$ mm

Where, in a ship with longitudinal bottom stiffening, the bilge strake is stiffened transversely the thickness of this strake is to be as given by the following formula, but need not exceed that of the bottom or side shell, whichever is the greater :—

(c) $\frac{s}{3450}(L_1 + 165)\sqrt{\frac{d}{L_1}}$ mm

(In (a), (b) and (c) s is not to be taken as less than $\frac{L_1}{0,6} + 510$ mm, except when the actual spacing is considerably less than this value.)

or in British units:—

(a) Longitudinal framing... $\frac{s}{9\cdot84}\left(\frac{L_1 + 246}{1000}\right)\sqrt{\frac{d}{L_1}}$ in

(b) Transverse framing ... $\frac{s}{9\cdot84}\left(\frac{L + 541}{1000}\right)\sqrt{\frac{d}{L}}$ in

Where, in a ship with longitudinal bottom stiffening, the bilge strake is stiffened transversely the thickness of this strake is to be as given by the following formula, but need not exceed that of the bottom or side shell, whichever is the greater:—

(c) $\frac{s}{11\cdot32}\left(\frac{L_1 + 541}{1000}\right)\sqrt{\frac{d}{L_1}}$ in

(In (a), (b) and (c) s is not to be taken as less than $\frac{L_1}{50} + 20$ in, except when the actual spacing is considerably less than this value.)

Where the bilge is stiffened longitudinally the thickness is to be determined from (a) above with an equivalent spacing s_1 as determined from D 4304.

The midship thickness is to extend over 0,4L amidships and is to be tapered gradually to the end thickness.

For grades of steel, *see* 512 and 513.
For strengthening of bottom forward, *see* D 10.
For transversely framed ships, *see also* 515.

Side Shell

505 The thickness of side shell plating amidships is to be not less than:—

$$t = \frac{s+150}{640}\sqrt{\frac{d\,L}{D}}\ \text{mm}$$

but in no case is to be less than that required by 508.

(d is not to be taken as less than $\frac{L_1}{20}$ and s not less than $559+1{,}11L$ mm or 865 mm, whichever is the lesser.)

Where the side shell is framed longitudinally, s is to be the spacing of longitudinals reduced by $100\left(1-\frac{250S}{s}\right)$ mm, except when $100\left(1-\frac{250S}{s}\right)$ is negative,

or in British units:—

$$t = \frac{s+6}{1160}\sqrt{\frac{d\,L}{D}}\ \text{in}$$

but in no case is to be less than that required by 508.

(d is not to be taken as less than $\frac{L_1}{20}$ and s not less than $22 + \frac{L}{75}$ in or 34 in, whichever is the lesser.)

Where the side shell is framed longitudinally, s is to be the spacing of longitudinals reduced by $4 - \frac{12S}{s}$ in, except when $4 - \frac{12S}{s}$ is negative.

The midship thickness is to extend over 0,4L amidships and is to be tapered gradually to the end thickness. The thickness may have to be increased to comply with 507.

The thickness of side shell need not exceed that determined from 504(a) or (b) using the spacing of side shell frames or longitudinals.

506 Where the shear force has to be investigated (*see* D 303), the shear stress at the neutral axis is to be calculated as:—

$$\frac{100F\,A\bar{y}}{I\,t}\ \text{kg/mm}^2\ \left(\frac{F\,A\bar{y}}{12\,I\,t}\ \text{ton/in}^2\right)$$

where F = shear force in still water, in tonnes (tons), taking into account local forces at transverse bulkheads, where applicable. (*See* D 941),

$A\bar{y}$ = first moment of area of the longitudinal material above the neutral axis, in cm^3 ($in^2\,ft$),

I = moment of inertia of the transverse section in cm^4 ($in^2\,ft^2$),

t = combined thickness, in mm (in), of side shell and longitudinal bulkheads, if fitted, for both sides of the ship, at the neutral axis.

NOTE:—The values of $A\bar{y}$ and I for the midship section may be used for the calculation of the shear stress at any point along the length of the ship.

507 If the shear stress at any point along the ship's length exceeds the value derived from Table D 5.1, then the side shell in way is to be increased in thickness or, where specially approved, stiffened by intermediate frames.

TABLE D 5.1

STATION	SHEAR STRESS	STATION	SHEAR STRESS
	kg/mm² (ton/in²)		kg/mm² (ton/in²)
AP	8,25 (5·23)	5½	7,65 (4·84)
½	7,81 (4·95)	6	7,21 (4·57)
1	7,37 (4·68)	6½	6,77 (4·29)
1½	6,93 (4·40)	7	6,49 (4·13)
2	6,66 (4·24)	7½	6,49 (4·13)
2½	6,49 (4·13)	8	6,66 (4·24)
3	6,60 (4·18)	8½	7,04 (4·46)
3½	6,82 (4·35)	9	7,54 (4·79)
4	7,26 (4·62)	9½	7,98 (5·06)
4½	7,81 (4·95)	FP	8,25 (5·23)
5	8,25 (5·23)	—	—

End Thickness

508 The thickness of shell plating for 0,075L from the ends is not to be less than:—

$$\left(6{,}5 + \frac{L}{30}\right)\sqrt{\frac{s}{s_b}}\ \text{mm} \qquad \left(\left(0{\cdot}255 + \frac{L}{2500}\right)\sqrt{\frac{s}{s_b}}\ \text{in}\right)$$

where s_b = standard frame spacing, in mm (in), as given in D 705 and D 706.

Sheerstrake

509 The width of sheerstrake amidships is not to be less than 150D mm (1·8D in), but need not exceed 2135 mm (84 in), and the thickness is not to be less than that of the deck plating or the side shell, whichever is the greater.

At ends, the thickness may be the same as the side shell, but provided the draught does not exceed 0·7D (D being measured to the uppermost continuous deck) the end thickness may be as required for a poop or forecastle.

For increase in thickness at ends of superstructure, *see* D 1715.

510 The upper edge of the sheerstrake is to be dressed smooth and kept free of isolated welded fittings or connections. Bulwarks are not to be welded to the top of the sheerstrake within 0,5L amidships. In ships over 150 m (492 ft) in length, scupper openings are not to be cut above the deck within 0,5L amidships or in way of breaks of superstructures.

511 Where a rounded sheerstrake is adopted, the radius should, in general, not be less than 15 times the thickness. Where Grade E plates are subjected to severe cold working, or where local heating of the plating is adopted, it may be necessary to require re-normalising of the plate. The welding of fairleads or other fittings to this plate is to be kept to a minimum and details are to be submitted.

Grades of Steel

512 In ships between 105 and 135 m (344·5 and 443 ft) in length the sheerstrake from 0,2L aft of amidships to 0,2L forward of amidships is to be Grade D irrespective of thickness unless the gunwale connection is riveted.

Elsewhere, when the thickness of plating exceeds 20,5 mm (0·80 in) steel of Grade D will generally be required as follows:—

(a) Bottom shell to upper turn of bilge—from 0,15L aft of amidships to 0,15L forward of amidships when the length is 153 m (503 ft) and below, and from 0,2L aft of amidships to 0,2L forward of amidships where the length is 215 m (705 ft) and above, with intermediate values obtained by interpolation.

Where the bottom plating is required to be of Grade D, the keel plate is also to be of this grade.

(b) Sheerstrake:—

(i) from 0,2L aft of amidships to 0,2L forward of amidships,

(ii) at the poop front and at the ends of the bridge,

(iii) outside the limits given in (i), when the thickness exceeds 25,5 mm (1·00 in).

513 Strakes of Grade E steel are to be arranged as follows:—

LENGTH L		GRADE E STRAKES
OVER	NOT EXCEEDING	
metres (feet)	metres (feet)	
135 (443)	170 (558)	Sheerstrake (*see* Note 1)
170 (558)	200 (656)	Sheerstrake
200 (656)		Sheerstrake Bilge strake Keel (*see* Note 2)

NOTES:—1. In ships between 135 and 170 m (443 and 558 ft) in length, the sheerstrake may be Grade D provided the deck plating is also Grade D.

2. In ships exceeding 200 m (656 ft) in length, the keel may be Grade D provided the bottom plating is also Grade D.

The Grade E strakes are to extend between 0,2L aft and 0,2L forward of amidships.

The breadth of each strake is not to be less than 1500 mm (60 in), except that the bilge strake shall not be less than 1800 mm (71 in) and the keel shall be as required by 503.

Riveted seams or connections will be accepted as alternatives to strakes of Grade E steel.

Openings in Sheerstrake or Shell Plating

514 Cargo door openings are to have well rounded corners. A plan of structure in way of doors indicating proposed compensation is to be submitted for approval.

Sea inlets, or other openings, are to have well rounded corners and, as far as possible, should be kept clear of the bilge radius. Openings on, or near to, the bilge radius should be elliptical. The thickness of sea inlet boxes should be the same as the adjacent shell, but not less than 12,5 mm (0·50 in).

In general, compensation will not be required for holes in the sheerstrake which are clear of any deck openings outside the line of the main hatchways, and whose depth does not exceed 20 per cent of the depth of the sheerstrake or 380 mm (15 in), whichever is the lesser.

Local Stiffening of Bottom Shell

515 In ships with all-welded, transversely framed bottom construction, additional longitudinal stiffeners are to be fitted for 0·4L amidships.

Local Strengthening

516 The thickness of plates connected to the sternframe or propeller brackets is not to be less than 50 per cent greater than that required for shell at ends.

Plating in way of hawsepipe is to be suitably increased.

For strengthening for navigation in ice, *see* D 24.

Bilge Keels

517 Where bilge keels are fitted, it is desirable that they be attached to a continuous flat bar which may be welded to the shell. Scallops are to be arranged at welded butts in the flat bar, or alternatively, a 25,5 mm (1 in) hole should be drilled in the butt weld just above the fillet weld; in this case, the fillet weld is to be continuous.

Alternative arrangements, or arrangements omitting the flat bar, will be considered.

Bilge keels are to be gradually tapered at their ends and are not to finish on an unstiffened panel.

Higher Tensile Steel

518 When higher tensile steel is used, the scantlings are to be determined in accordance with D 65, D 66 and D 67.

519 When higher tensile steel is used amidships and mild steel at the ends, the taper line for the mild steel is to be determined using a nominal mild steel midship thickness of:—

(a) higher tensile thickness/k or,
if the higher tensile steel thickness is based upon minimum thickness requirements:—

(b) the minimum mild steel thickness determined from 504.

The higher tensile steel thickness, outside the midship 0,4L, is to be based upon a taper line from the midship thickness at 0,2L aft or forward of amidships to any point on the mild steel taper line.

Section 6

LONGITUDINAL FRAMING

Symbols

601 L = length of ship, in metres (feet).

L_1 = length of ship, in metres (feet), but need not to be taken as greater than 215 m (705 ft). (*See also* line 8, Table D 6.1).

d = moulded draught, in metres (feet).

s = spacing of longitudinals, in mm (in).

S = span of longitudinals, in metres (feet).

D = moulded depth, in metres (feet), to the uppermost continuous deck.

H = height from tank top to deck at side amidships, in metres (feet).

Weather Decks

602 The section modulus of weather deck longitudinals is not to be less than:—

$$\frac{I}{y} = \frac{K_1 s h}{100} + \frac{K_2 s}{100}\left(\frac{S L_1}{100}\right)^2 \text{cm}^3$$

$$\left(\frac{I}{y} = \frac{K_1 s h}{100} + \frac{K_2 s}{100}\left(\frac{S L_1}{1000}\right)^2 \text{in}^3\right)$$

where K_1, K_2 and h are taken from Table D 6.1.

603 If the longitudinals carry hanging cargo, such as chilled beef, the modulus determined from 602 is to be increased by 50 per cent if the height of the 'tween deck below is 2,6 m (8·5 ft) or less, and 100 per cent if the height is 3,2 m (10·5 ft) (with intermediate heights in proportion) but the modulus need not exceed that derived from 605 for a 2,6 m (8·5 ft) 'tween deck height above. No increase is required if the modulus derived from 605 is less than that derived from 602.

TABLE D 6.1

LINE	LOCATION OF WEATHER DECK LONGITUDINAL	K_1	K_2	h
1	0,4L amidships outside line of openings... (*See* Note 2)	5,70 (2·7)	0.72 (0·96)	1,2+2,04E (4+6·7E) but not less than 1,2 (4·0) nor greater than 1,5 (5·0) (*See* Note 3)
2	At 0,12L from F.P. outside line of openings	4,85 (2·3)	0,62 (0·83)	
3	At and abaft 0,1L from A.P.	4,00 (1·9)	0,50 (0·67)	
4	Abaft 0,12L from F.P. within line of openings	4,00 (1·9)	0,50 (0·67)	
5	Between 0,12L and 0,075L from F.P. outside and inside line of openings ...	5,70 (2·7)	0,72 (0·96)	1,5 (5·0)
6	Forward of 0,075L from F.P. outside and inside line of openings	6,35 (3·0)	0,78 (1·04)	1,8 (6·0)
7	Bridge where forming an effective superstructure...	6,75 (3·2)	0,72 (0·96)	0,9+2,04E (3+6·7E) but not less than 0,9 (3·0) nor greater than 1,2 (4·0)
8	Short bridge or poop ... ... (L_1 for short bridge or poop need not be taken as greater than 153 m (502 ft))	4,65 (2·2)	0,50 (0·67)	

NOTES:—1. $E = \dfrac{0{,}0914+0{,}003L}{D-d} - 0{,}15$

$$\left(E = \frac{0\cdot3+0\cdot003L}{D-d} - 0\cdot15 \text{ British}\right)$$

2. The amidship scantlings of longitudinals as determined from Line 1 may be tapered to the values determined from Lines 2 and 3.

3. For decks above the uppermost continuous deck, h obtained from the formula for lines 1 to 4 can be successively reduced by 0,31 m (1·02 ft) for each deck to a minimum of 0,45 m (1·48 ft).

Cargo and Accommodation Decks

604 The section modulus of cargo and accommodation deck longitudinals is not to be less than:—

$$\frac{I}{y} = \frac{K\,s\,L_1 + 25\,h\,s\,S^2}{10\,000}\ \text{cm}^3$$

$$\left(\frac{I}{y} = \frac{K\,s\,L_1 + 1\cdot1\,h\,s\,S^2}{10\,000}\ \text{in}^3\right)$$

where K = 5,9 (2·8) for cargo decks.
5,1 (2·4) for accommodation decks.

h = load height in metres (feet) as given in D 809.

Where fork lift trucks are to be used on the deck, the section modulus of longitudinals is not to be less than required by D 811, taking S and s in the formula as defined in 601, or the value derived above or by 605 if appropriate, whichever is the greater.

For permissible deck loading appropriate to Rule scantlings and for scantlings for specific loadings, *see* D 25.

605 If cargo deck longitudinals carry hanging cargo such as chilled beef, and may be simultaneously loaded above with cargo, the modulus is to be determined from 604 with h increased by 0,76 m (2·5 ft) if the height of

the 'tween deck below is 2,6 m (8·5 ft) or less and 2,29 m (7·5 ft) if the height is 3,8 m (12·5 ft) (with intermediate heights in proportion). A similar addition is to be made, if appropriate, to accommodation deck longitudinals.

Bottom Longitudinals

606 The section modulus is not to be less than:—

$$\frac{I}{y} = \frac{s\, d\, (S + 3{,}05)^2 \sqrt{L_1 + 380}}{11\,500}\ \text{cm}^3$$

$$\left(\frac{I}{y} = \frac{s\, d\, (S + 10)^2 \sqrt{L_1 + 1250}}{475\,000}\ \text{in}^3\right)$$

607 The unsupported span of the longitudinals is not to exceed 2,5 m (8·2 ft). With longer spans, struts having scantlings derived from D 918 with Z taken as the modulus of the bottom longitudinal given by 606 are to be fitted, except when a notation regarding the carriage of heavy cargoes is to be assigned. In this case, the spacing of floors is not to exceed 2,5 m (8·2 ft). The scantlings of the longitudinals adjacent to the centre girder and the margin plate may be based on a span of 1,25 m (4·1 ft).

Inner Bottom Longitudinals

608 Class 100A1 without notations.

The section modulus is not to be less than 85 per cent of the values calculated from 606.

609 "Strengthened for Heavy or Ore Cargoes" notation.

The section modulus of rolled sections is not to be less than 85 per cent of the bottom longitudinals nor less than:—

$$\frac{I}{y} = \frac{S^2\, s\, H}{77}\ \text{cm}^3 \qquad \left(\frac{I}{y} = \frac{S^2\, s\, H}{1755}\ \text{in}^3\right)$$

If plate girders are fitted alternately with rolled sections, the section modulus, as determined above, may be reduced by 10 per cent. The girders are to have a thickness derived from D 927.

610 "Strengthened for Heavy or Ore Cargoes—Specified Holds may be Empty" notation.

The section modulus of rolled sections is not to be less than:—

$$\frac{I}{y} = \frac{S^2\, s\, H}{C}\ \text{cm}^3\ (\text{in}^3)$$

where

$C = 89 \times$ stowage rate (m^3/tonne)

or in British units:—

$C = 56{\cdot}5 \times$ stowage rate (ft^3/ton)

"Stowage rate" is the cubic capacity of holds, excluding hatchways, divided by the cargo deadweight or, in specific cases, is the cubic capacity of a particular hold divided by the weight of cargo stowed therein.

Longitudinal Side Framing

611 The section modulus of side longitudinals is not to be less than:—

$$\frac{I}{y} = \frac{s\, S^2}{120}\left(h_1 + \frac{2{,}5d - D}{6}\right)\ \text{cm}^3$$

$$\left(\frac{I}{y} = \frac{s\, S^2}{2730}\left(h_1 + \frac{2{\cdot}5d - D}{6}\right)\ \text{in}^3\right)$$

where h_1 = distance of longitudinal below deck at side, in metres (feet) and d is not to be taken as less than 0,4D. The section modulus need not exceed that determined from 606 for bottom longitudinals, but where the span of the side longitudinals exceeds 2,5 m (8·2 ft) this modulus should be determined from 606 with S = 2,5 m (8·2 ft) and increased by the factor:—

$$\left(\frac{\text{Span of side longitudinals in metres (feet)}}{2{,}5\ \text{m}\ (8{\cdot}2\ \text{ft})}\right)^2$$

The section modulus of side longitudinals in topside wing tanks is to be that determined as above, but is not to be less than required for the sloping bulkhead (*see* 615).

612 Webs supporting side longitudinals are, in general, not to be spaced more than 3,7 m (12·1 ft) apart when the length L does not exceed 185 m (605 ft) and $\frac{L}{50}$ for lengths greater than this, and their section modulus is not to be less than:—

$$\frac{I}{y} = 10\, s_1\, h_2\, S_1^2\ \text{cm}^3$$

$$\left(\frac{I}{y} = \frac{s_1\, h_2\, S_1^2}{190}\ \text{in}^3\right)$$

where s_1 = spacing of webs, in metres (feet),

h_2 = distance, in metres (feet), from mid-point of span to upper deck at side amidships,

S_1 = span of web, in metres (feet).

Where topside tanks are fitted or an Ore or Heavy Cargo notation is to be assigned, the strength of these webs may require to be increased. In general, the standard of strength is not to be less than that required by D 715, D 716 and D 717.

For arrangements in machinery spaces at aft end, *see* D 55.

For arrangements in fore and aft peaks, *see* D 54 and D 55.

Bilge Longitudinals

613 The scantlings of bilge longitudinals are to be graduated between those required for the bottom longitudinals and lowest side longitudinal.

Hopper Side Tanks

614 If longitudinals are fitted to the sloping tank top forming a hopper side tank, their section modulus is not to be less than required by 608, 609 or 610, as appropriate. H may, in this case, be measured vertically from the centre of the sloping portion to the intersection with the sloping plating of the topside tank, or to the deck at side if no topside tank is fitted.

Topside Wing Tank

615 Longitudinals on the sloping bulkhead of topside tanks are to have a section modulus not less than:—

$$\frac{I}{y} = \frac{H_1 \, s \, S^2}{100} \text{ cm}^3 \qquad \left(\frac{I}{y} = \frac{H_1 \, s \, S^2}{2275} \text{ in}^3\right)$$

where H_1 is the greater of the following heads, in metres (feet):—

(a) measured from the outboard longitudinal to the gunwale or outboard corner of the tank,

(b) two-thirds of the distance, measured parallel to the plating, from the outboard longitudinal to the inboard corner of the tank.

Where a plate diaphragm is fitted the longitudinals inboard of this may be determined using H equal to the perpendicular distance between the sloping bulkhead and the gunwale or outboard corner of the tank.

General

616 The thickness of flat bar longitudinals continuous at bulkheads is not to be less than one-eighteenth of the depth. Where not continuous, the thickness should not be less than one-fifteenth of the depth.

Longitudinals of the flat bar type are not to be scalloped, but isolated drain or air holes may be provided.

Flat bar type longitudinals (where cut from plates) and through brackets are to be steel of Grade D within 0,4L amidships when the thickness exceeds 20,5 mm (0·80 in).

Built longitudinals are to comply with the requirements of D 4404.

617 Where the L exceeds 215 m (705 ft) the bottom and deck longitudinals should be continuous through the transverse bulkheads, but alternative arrangements will be considered.

618 End connections of longitudinals to bulkheads are to provide adequate fixity and, so far as practicable, direct continuity of longitudinal strength.

Section 7

TRANSVERSE SIDE FRAMING

Symbols

701 L = length of ship, in metres (feet).

D = moulded depth, in metres (feet).

D_1 = D but need not be taken as greater than 1,6d.

D_2 = D but need not be taken as greater than 1,6d or 16 m (52·5 ft) whichever is the lesser.

d = moulded draught, in metres (feet).

s = frame spacing, in (mm) in.

H = (a) Main frames—vertical framing depth, in metres (feet), measured at side as indicated in Figs. D 7.1 and D 7.2.

(b) 'Tween deck frames—vertical 'tween deck height, in metres (feet), measured at side. In way of sheer, H is to be measured, in general, at the middle of the length of each compartment. Where sheer is excessive, H will be specially considered.

Values of H in (a) and (b) are not to be less than 2,5 m (8·2 ft).

$K = 1 - \dfrac{x}{5q}$ but not less than 0,35.

x = distance, in (metres) feet, measured as shown in Fig. D 7.2.

q = minimum height of double bottom, in metres (feet), as determined from D 904.

f = factor, obtained from Fig. D 7.3.

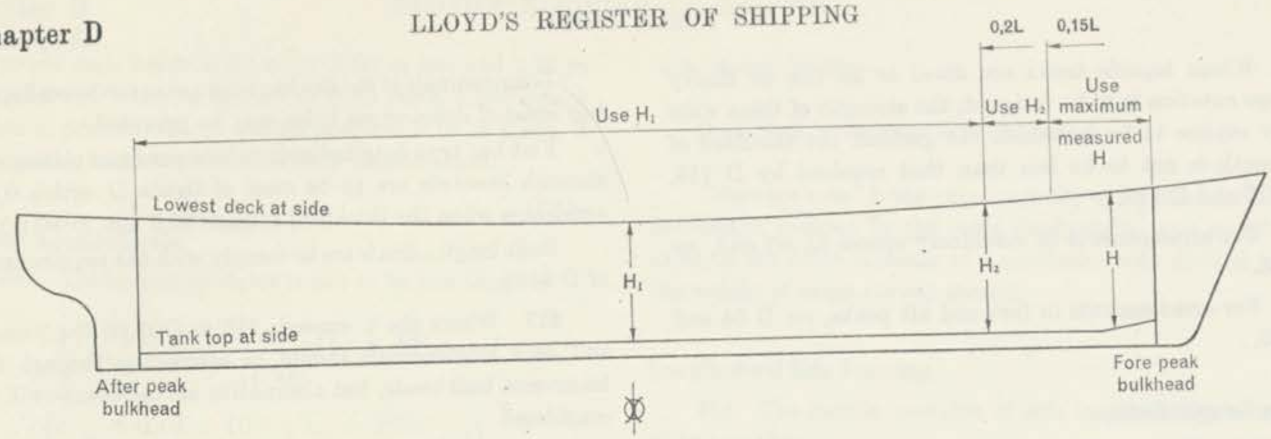


FIG. D 7.1—measurement of H for main frames allowing for sheer.

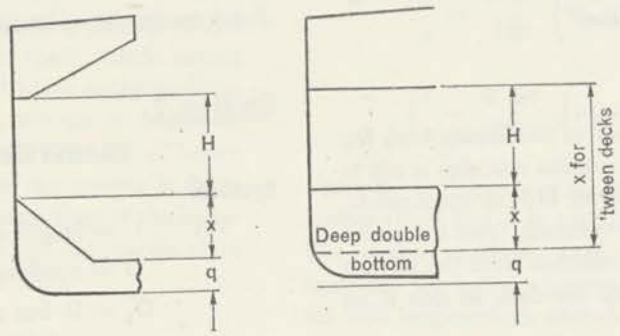


FIG. D 7.2—measurement of H, x and q where a hopper side tank or deep double bottom is fitted. (For 'tween decks x is to be measured excluding sheer).

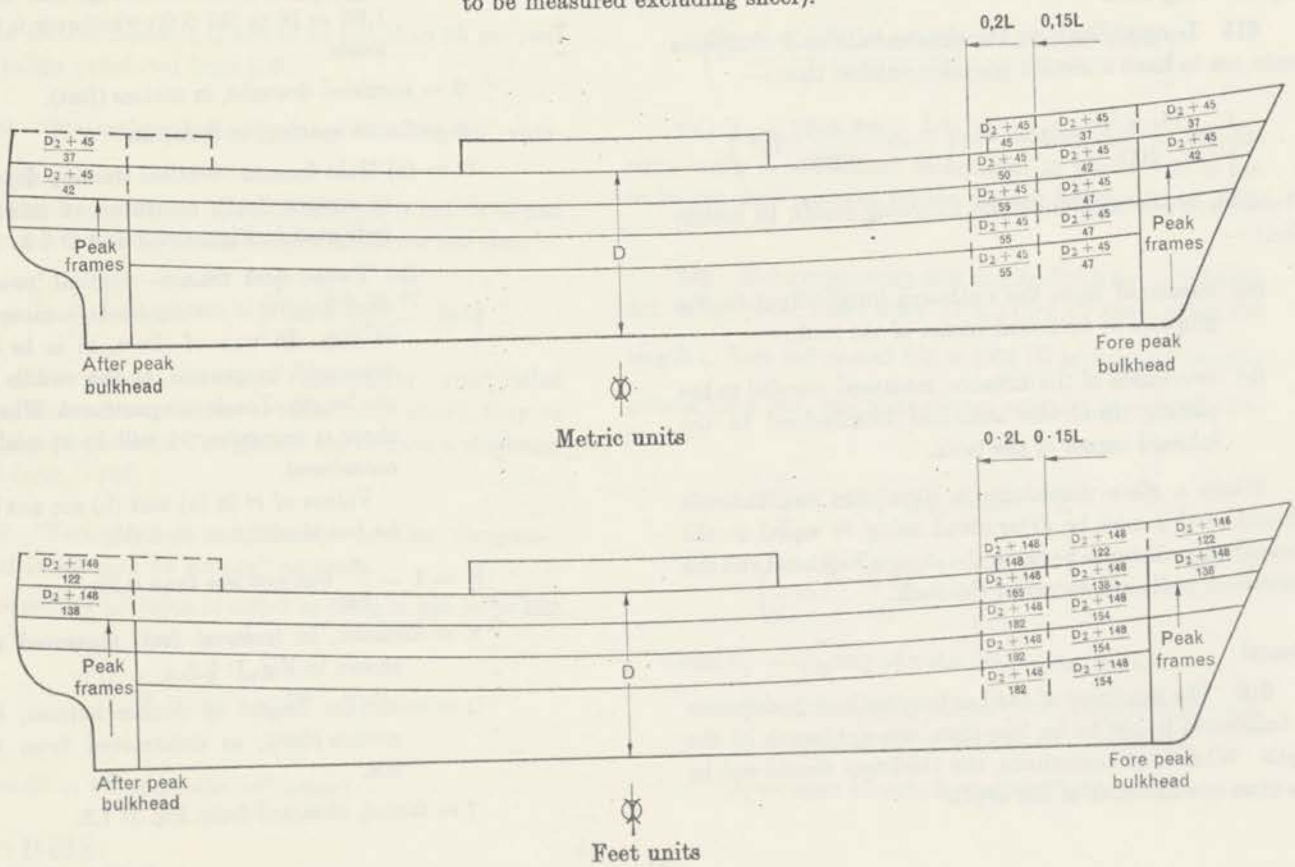


FIG. D 7.3—showing distribution of factor f.

General

702 All scantlings for main frames are based on Rule welded end connections. If brackets differing from Rule size are fitted, the modulus of the frame is to be corrected—*see* 731.

703 The minimum inertia for all frames is given in 725.

Frame Spacing

704 The frame spacing between 0,2L from forward and the after peak bulkhead is not, in general, to exceed 1000 mm (39·4 in).

705 The frame spacing between 0,2L from forward and the fore peak bulkhead is not, in general, to exceed 700 mm (27·5 in) where D_1 is greater than 8,9 m (29 ft) and $\frac{1000D_1}{24} + 330$ mm $\left(\frac{D_1}{2} + 13 \text{ in}\right)$ where D_1 is less than 8,9 m (29 ft).

706 The frame spacing in peaks and cruiser sterns is not, in general, to exceed 610 mm (24 in).

Main and 'Tween Deck Frames

707 The section modulus of main and 'tween deck frames is not to be less than:—

between 0,2L aft of the forward perpendicular and the after peak bulkhead,

$$\frac{I}{y} = \frac{Pds}{760} \text{ cm}^3 \qquad \left(\frac{I}{y} = \frac{Pds}{30} \text{ in}^3\right) \tag{1}$$

between 0,2L aft of the forward perpendicular and the line of the fore peak bulkhead,

$$\frac{I}{y} = \frac{Pdsf}{700} \text{ cm}^3 \qquad \left(\frac{I}{y} = \frac{Pdsf}{27\cdot5} \text{ in}^3\right) \tag{2}$$

'tween deck frames aft of the line of the after peak bulkhead and forward of the line of the fore peak bulkhead,

$$\frac{I}{y} = \frac{Pdsf}{610} \text{ cm}^3 \qquad \left(\frac{I}{y} = \frac{Pdsf}{24} \text{ in}^3\right) \tag{3}$$

In (1), (2) and (3) above, P depends on where the lower end of the frame is connected as follows:—

to a double bottom of Rule height (main frame),

$$P = 1{,}35H^2 + 0{,}11D_1^2 + 11 \tag{4}$$

$$\left(P = \frac{H^2}{428} + \frac{D_1^2}{5260} + 0\cdot205 \text{ British}\right)$$

to a hopper side tank or to a deep double bottom (main frame),

$$P = (1{,}35H^2 + 0{,}11KD_1^2 + 11)\left(1 - \frac{x}{1{,}4D}\right) \tag{5}$$

$$\left(P = \left(\frac{H^2}{428} + \frac{KD_1^2}{5260} + 0\cdot205\right)\left(1 - \frac{x}{1\cdot4D}\right) \text{ British}\right)$$

Where, due to the shape of the ship towards the ends, the rigidity of the hopper side tank is reduced, the modulus of the main frame may require to be increased.

to a deck or flat ('tween deck frame—*see also* 709),

$$P = (1{,}35H^2 + 0{,}11D_1^2 + 11)\left(1 - \frac{x}{1{,}4D}\right) \tag{6}$$

$$\left(P = \left(\frac{H^2}{428} + \frac{D_1^2}{5260} + 0\cdot205\right)\left(1 - \frac{x}{1\cdot4D}\right) \text{ British}\right)$$

708 Where spans forward of 0,2L from the fore perpendicular are in excess of 9 m (29·5 ft), intercostal stringers are to be fitted in line with alternate peak stringers.

709 The minimum section modulus of a 'tween deck frame is not to be less than:—

$$\frac{I}{y} = \frac{D_1 s}{110} \text{ cm}^3 \qquad \left(\frac{I}{y} = \frac{D_1 s}{230} \text{ in}^3\right)$$

710 At positions where there are more than four decks, the modulus in 707 may be reduced and the minimum modulus of the 'tween deck frames will be specially considered.

711 The four frames nearest the end of a superstructure which terminates within 0,25L amidships are to extend from the 'tween decks below to the superstructure deck. Equivalent arrangements are to be made when the ship's side is framed longitudinally.

712 All 'tween deck and superstructure frames are to be efficiently scarphed to the main frames below or effectively attached to the deck. For end connections and welding, *see* 727 to 735.

Peak Frames

713 The frames in the fore and aft peaks are to extend as indicated in Fig. D 7.3, and are to have a section modulus not less than:—

$$\frac{I}{y} = 2{,}8 \, d \, D_2 \text{ cm}^3 \qquad \left(\frac{I}{y} = 0\cdot0159 \, d \, D_2 \text{ in}^3\right)$$

This modulus applies in conjunction with Rule side stringers spaced vertically 2,0 m (6·56 ft) apart in the fore peak tank, and 2,5 m (8·2 ft) in the after peak tank (*see* D 11) and with a 'tween deck height of 2,6 m (8·5 ft) above the peak tanks, measured vertically.

Where the spacing of the stringers exceeds 2,0 or 2,5 m (6·56 or 8·2 ft), the modulus of the frames is to be increased in direct proportion.

Where the 'tween deck height above the peak tanks exceeds 2,6 m (8·5 ft), or where curvature or slope is very great, intermediate stringers may be required.

714 Web frames are to be arranged in the 'tween decks above the after peak tank at every fourth frame abaft the after peak bulkhead, and are to have a section modulus not less than that required by D 5512.

Web Frames, or Frames of Increased Scantlings, in Cargo Holds

715 Where topside tanks are fitted, vertical web frames are to be fitted in line with the topside tank transverses (*see also* D 1918), and are to have a section modulus not less than:—

$$\frac{I}{y} = \frac{(2D - H - q - x)\,l H s_1}{7{,}0} + \left(\frac{I}{y}\right)_f \left(1 - \frac{n}{4}\right) \text{cm}^3$$

$$\left(\frac{I}{y} = \frac{(2D - H - q - x)\,l H s_1}{13\,300} + \left(\frac{I}{y}\right)_f \left(1 - \frac{n}{4}\right) \text{in}^3\right)$$

or the section modulus of the adjacent main frame, whichever is the greater.

where l = length of hold, in metres (feet),

s_1 = spacing of web frames, in metres (feet),

$\left(\frac{I}{y}\right)_f$ = section modulus of main frame in cm³ (in³) obtained from 707,

n = number of frame spaces between adjacent web frames.

Alternatively, the scantlings of the main frames may be increased to comply with the above formula, in which case $n = 1$, and s_1 = frame spacing, in metres (feet).

716 If a notation regarding the carriage of "Heavy Cargoes" or "Ore Cargoes" is to be assigned the modulus as required by 707 or, if topside tanks are fitted by 715, is to be increased by 4 per cent.

717 If a notation regarding the carriage of "Heavy Cargoes" or "Ore Cargoes" is to be assigned in association with specified holds being empty, web frames may require to be fitted within the middle half-length of each hold.

The combined modulus of the frames (determined from 707 and corrected by 715 and 716 if applicable) within the middle half-length is to be multiplied by the factor:—

$$\frac{4\,w\,(1 - k_1)}{d} \qquad \left(\frac{144\,w\,(1 - k_1)}{d} \text{ British}\right)$$

when this is greater than unity,

where w = double bottom loading, *see* D 941,

k_1 = factor determined from D 941.

Where the depth of double bottom exceeds that required by D 9, the above factor may be multiplied by

$$\left(\frac{\text{Rule depth}}{\text{Actual depth}}\right)^2$$

The combined modulus so derived is to be attained by fitting a suitable number of web frames which must be within the middle half-length of the hold, and in line with transverses in the top side tanks (if fitted).

Frames in Engine and Boiler Room

718 Vertical web frames are, in general, to be fitted in the engine room.

The combined section modulus of web and main frames is to be not less than 50 per cent greater than that of the Rule main frames up to the lowest deck above the waterline.

The web frames in midship machinery spaces may be omitted provided the overall strength is maintained.

Where machinery spaces are at the after end, the arrangements are to comply with D 55.

Side Framing in way of Tanks

719 Paragraphs 720 to 722 apply to oil fuel bunkers, settling tanks, and deep tanks used for water ballast or cargo oil.

720 The section modulus derived in accordance with 707 is to be increased by 15 per cent (except where the tank is situated forward of 0,15L) but may require to be further increased to comply with 721.

721 Where the top of the tank is above the head of the frame the modulus is to be that given by the following formula or as required by 720, whichever is the greater:—

$$\frac{I}{y} = \frac{s H^2 h}{150} \text{ cm}^3 \qquad \left(\frac{I}{y} = \frac{s H^2 h}{3430} \text{ in}^3\right)$$

where s = frame spacing, in mm (in),

H as defined in 701. (*See* also 722),

h = head, in metres (feet), measured from the middle of H to the deck at side or half the head from the middle of H to the top of the overflow, whichever is the greater.

722 Where fully supporting side stringers, having scantlings according to D 19 are fitted, H may be measured between stringers, or between the stringer and the deck or tank top.

Frames under Hatch End Beams supporting Hatch Side Girders or in way of Deck Transverses

723 The section modulus of these frames is not to be less than:—

$$\frac{I}{y} = 2{,}5\left(\frac{l^2}{5} + H^2\right) h_t S_t \text{ cm}^3$$

or in British units:—

$$\frac{I}{y} = \left(\frac{l^2}{5} + H^2\right) \frac{h_t S_t}{760} \text{ in}^3$$

where l = distance, in metres (feet), from side shell to inboard support of beam or transverse,

H = vertical framing depth or 'tween deck height of frame concerned, as defined in 701 but need not be taken greater than 3,5 m (11·5 ft),

h_t = load height, in metres (feet), as given in D 6 and D 8. (*See also* D 1304, D 1319 and D 25),

S_t is defined as follows:—

(a) at hatch end beams S_t = length of hatch, in metres (feet), divided by 4, but not less than that given in (b),

(b) at transverses S_t = actual spacing of transverses, in metres (feet).

In no case is the modulus to be less than that required for the normal side frame.

724 Where the modulus required for frames under deck transverses exceeds that obtained from 707 and 720 to 722, the intermediate frames may be reduced provided the combined modulus is maintained and the reduction in any intermediate frame is not greater than 35 per cent. The reduced modulus is not to be less than that given in 709.

Additional Requirements

725 The inertia of a frame or web frame is not to be less than:—

(a) In the forward 0,15L

$$I = 3{,}5\, H \frac{I}{y} \text{ cm}^4 \quad \left(I = 0{\cdot}42\, H \frac{I}{y} \text{ in}^4\right)$$

(b) Elsewhere

$$I = 3{,}2\, H \frac{I}{y} \text{ cm}^4 \quad \left(I = 0{\cdot}38\, H \frac{I}{y} \text{ in}^4\right)$$

726 Where holes are drilled or punched in the inboard flange of frames, the size of the frame may require to be increased in order to maintain the required section modulus in way of the holes.

Beam Knees and Tank Side Brackets

727 In ships having more than three tiers of beams and where large areas of deck are arranged for accommodation, or where particular conditions of loading are contemplated, the requirements for beam knees will be considered with a view to their omission in certain areas without increase in modulus.

728 Where frames are connected to deck transverses and hatch end beams, the scantlings of the brackets are to be determined from D 1311.

729 Where web frames (*see* 715 to 717) have continuous face flats the end connections are to have strength equivalent to the requirements of 730 to 735.

730 The sketches in Fig. D 7.4 are intended to be diagrammatic only, to show the method of measuring the arm lengths of beam knees and tank side brackets.

Frame Correction and Rule Arms of Knees and Brackets

731 When the effective arm of the knee or bracket l_a (*see* Fig. D 7.4) differs from the Rule arm l, the frame modulus is to be multiplied by the factor below:—

$$\text{when } l_a < l \quad \text{factor} = 1{,}2 - 0{,}2\,\frac{l_a}{l}$$

$$\text{when } l_a > l \quad \text{factor} = 1{,}1 - 0{,}1\,\frac{l_a}{l}$$

where:—

(a) **For a beam knee:**—the Rule length of arm l, measured as indicated for a and b in Fig. D 7.4, is

$$21\sqrt{\frac{I}{y}} - 51 \text{ mm} \qquad \left(3{\cdot}35\sqrt{\frac{I}{y}} - 2 \text{ in}\right)$$

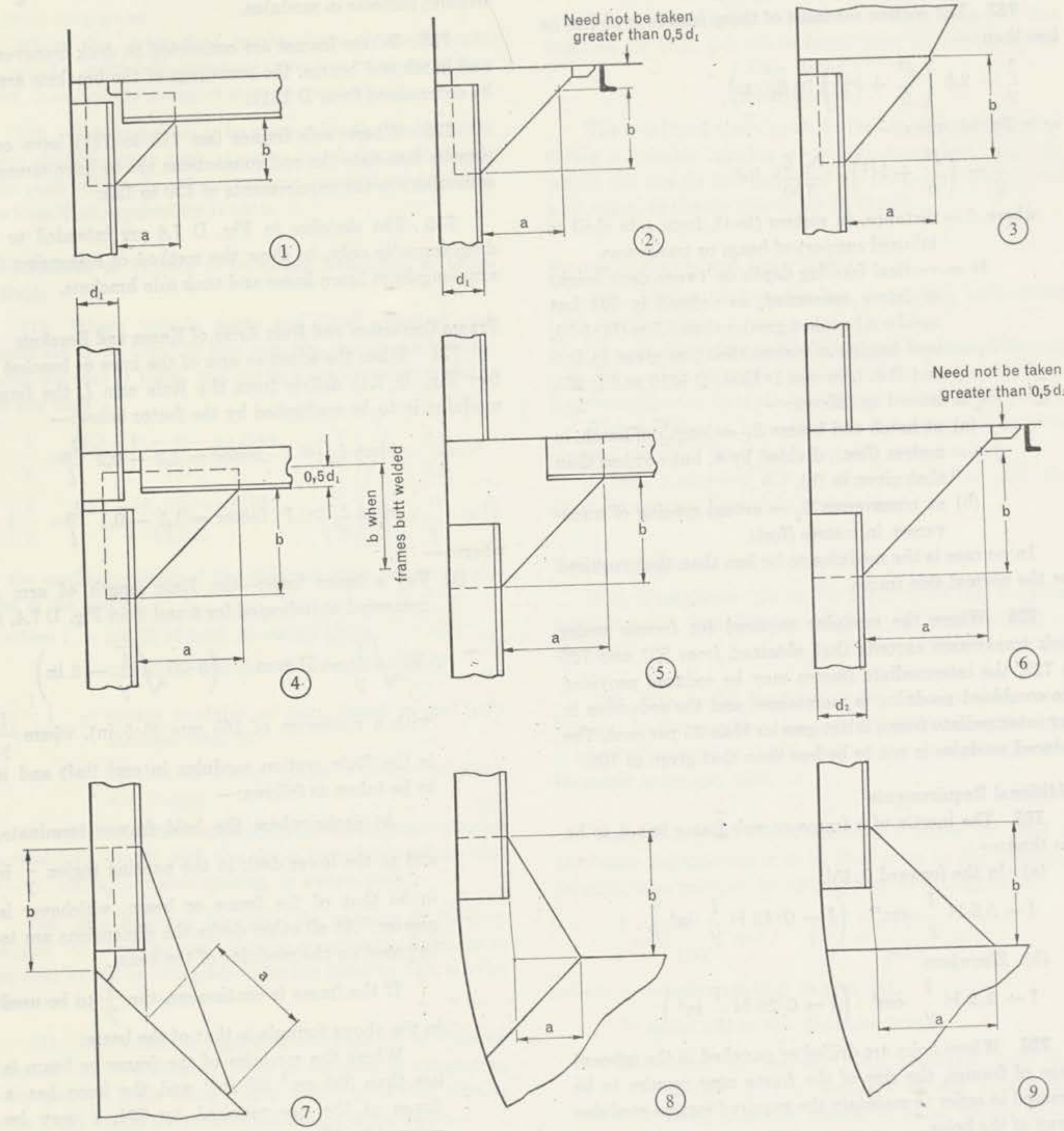
with a minimum of 165 mm (6·5 in), where $\frac{I}{y}$ is the Rule section modulus in cm³ (in³) and is to be taken as follows:—

At decks where the hold frames terminate, and at the lower deck in the panting region $\frac{I}{y}$ is to be that of the frame or beam, whichever is greater. At all other decks the dimensions are to be based on the modulus of the beam.

If the frame is continuous, the $\frac{I}{y}$ to be used in the above formula is that of the beam.

Where the modulus of the frame or beam is less than 590 cm³ (36 in³) and the knee has a flange of the size required by 734, l may be reduced by 15 per cent.

(b) **For a tank side bracket:**—where tank side brackets are connected to a double bottom or hopper side tank, l is to be taken not less than 20 per cent greater than that required for the beam knee, or 0,4 times the Rule height of double bottom, whichever is the greater.



Note:—Effective arm l_a to be used in 732 is $\frac{a+b}{2}$ but is not to be taken greater than 1,2 times a or b, whichever is the lesser.

Fig. D 7.4

Length of Overlap

732 The Rule length of overlap of knee or bracket on frame or beam, measured along the frame or beam, is not to be less than:—

$$11{,}3\sqrt{\frac{I}{y}} \text{ or } d_f \text{ mm} \qquad \left(1{\cdot}8\sqrt{\frac{I}{y}} \text{ or } d_f \text{ in}\right)$$

where $\frac{I}{y}$ is the Rule section modulus in cm^3 (in^3) and d_f is the depth in mm (inches), of the lower frame for types 2 to 4 and 6 to 9, in Fig. D 7.4 and of the beam or frame, whichever is the greater, for type 1. For type 5, $\frac{I}{y}$ is the modulus of the beam or the frame, as applicable.

For upper frames of types 4 to 6 the connection need only be that necessary to provide the required area of weld.

Welding

733 The weld area connecting the knee or bracket to beam or frame is not to be less than:—

$$2{,}4\sqrt{\frac{I}{y}} - 19{,}5 \text{ cm}^2 \text{ where } \frac{I}{y} < 345 \text{ cm}^3$$

$$\left(1{\cdot}5\sqrt{\frac{I}{y}} - 3 \text{ in}^2 \text{ where } \frac{I}{y} < 21 \text{ in}^3\right)$$

$$1{,}1\sqrt{\frac{I}{y}} + 4 \text{ cm}^2 \text{ where } \frac{I}{y} \geqslant 345 \text{ cm}^3$$

$$\left(0{\cdot}7\sqrt{\frac{I}{y}} + 0{\cdot}7 \text{ in}^2 \text{ where } \frac{I}{y} \geqslant 21 \text{ in}^3\right)$$

where $\frac{I}{y}$ is the section modulus as defined in 732.

For increased connection of tank side brackets to frames in the panting region, *see* D 1108.

The weld area connecting the upper frames to the deck for types 5 and 6 in Fig. D 7.4, is based on the modulus of the upper frame only.

In the above formulæ, and where the bracket or knee is connected to the deck or the shell, the weld throat thickness (leg length) is not to be less than $0{,}28\times$the plate thickness with a minimum of 3,5 mm ($0{\cdot}40\times$the plate thickness with a minimum of 0·18 in).

Flange

734 Where $\frac{I}{y}$ as defined in 731, is greater than 590 cm^3 (36 in^3) a flange of width not less than

$$2{,}1\sqrt{\frac{I}{y}} \text{ mm} \qquad \left(\frac{\sqrt{\frac{I}{y}}}{3} \text{ in}\right)$$

is to be fitted.

A flange may be required when $\frac{I}{y}$ is less than 590 cm^3 (36 in^3) depending upon the length of the bracket free edge.

Where frames are stopped above the tank top, tank side brackets are to be flanged or the free edge otherwise stiffened.

In no case should the width of the flange be less than 50 mm (2 in).

Thickness

735 The thickness of the knee or bracket is not to be less than:—

$$\left.\begin{array}{ll} \text{unflanged} & 4 + \dfrac{\sqrt{\frac{I}{y}}}{3} \text{ mm} \\[2ex] \text{flanged} & 2 + \dfrac{\sqrt{\frac{I}{y}}}{3} \text{ mm} \end{array}\right\} \begin{array}{l}\text{with a minimum of} \\ \text{7 mm for beam} \\ \text{knees, 8,5 mm for} \\ \text{tank side brackets,} \\ \text{and a maximum of} \\ \text{14 mm.}\end{array}$$

or in British units:—

$$\left.\begin{array}{ll} \text{unflanged} & 0{\cdot}16 + \dfrac{\sqrt{\frac{I}{y}}}{19} \text{ in} \\[2ex] \text{flanged} & 0{\cdot}08 + \dfrac{\sqrt{\frac{I}{y}}}{19} \text{ in} \end{array}\right\} \begin{array}{l}\text{with a minimum of} \\ \text{0·28 in for beam} \\ \text{knees, 0·34 in for} \\ \text{tank side brackets,} \\ \text{and a maximum of} \\ \text{0·55 in.}\end{array}$$

where $\frac{I}{y}$ is defined in 731.

Cross-references

736 For strengthening for navigation in ice, *see* D 24.
For side frames in conjunction with cantilever deck supports, *see* D 15.
Where an approved system of corrosion control is provided, *see* D 110.

Section 8

DECK BEAMS

Symbols

801 L = length of ship, in metres (feet).
B = moulded breadth, in metres (feet), but need not be taken greater than 21,5 m (70·5 ft).
D = moulded depth, in metres (feet).
d = moulded draught, in metres (feet).
S = span of beam, in metres (feet), but is not to be taken less than 1,83 m (6 ft). Forward of 0,075L aft of the fore perpendicular the span of forecastle and weather deck beams is not to exceed 3,7 m (12·1 ft). *See also* 803.
s = beam spacing, in mm (inches).
h = load height, in metres (feet). *See* 806, 809 and D 25.

General

802 Beams are to be fitted at every frame.

Beams at the crown of deep tanks, peak tanks and oil fuel tanks are to satisfy the requirements of this Section but are not to be less in strength standard than that required for the stiffeners of the boundary bulkheads to those tanks. *See* D 19.

803 Span to be used in the formulæ is to be measured in metres (feet) from girder to girder or from girder to a point midway between the toe of the bracket and the inner edge of the frame.

804 Where there are holes in the beam face flange the modulus of the beam may require to be increased.

805 For permissible deck loading appropriate to Rule scantlings and for scantlings for specific loadings, *see* D 25.

Weather Decks and Strength Decks other than Cargo Decks

806 The section modulus of weather deck beams and strength deck beams is not to be less than:—

$$\frac{1}{y} = \frac{K_1 K_2 d D}{1000} + \frac{K_3 h B S^2 s}{10\,000} \text{ cm}^3$$

$$\left(\frac{I}{y} = \frac{K_1 K_2 d D}{1000} + \frac{K_3 h B S^2 s}{100\,000} \text{ in}^3\right)$$

but the modulus need not exceed twice the value given by the second term in the formula.

K_1, K_2 and K_3 are given in Tables D 8.1, D 8.2 and D 8.3:—

TABLE D 8.1

Number of decks at the position of the beam under consideration, including superstructure decks, but excluding forecastles	K_1
1	20,0 (1·5)
2	13,3 (1·0)
3	10,5 (0·8)
4 or more	9,3 (0·7)

NOTES: (1) The K_1 value for a forecastle deck may be taken as 13,3 (1·0).

(2) A sloping topside tank may be counted as a deck.

TABLE D 8.2

LOCATION OF BEAM	K_2
Forward of a point 0,12L aft of the fore perpendicular	80,0 (6·0)
Short bridges and poops	13,3 (1·0)
Elsewhere	53,0 (4·0)

TABLE D 8.3

LOCATION OF BEAM	K_3
Beam span adjacent to ship's side	3,6 (0·48)
Forward of a point 0,075L abaft the fore perpendicular, on forecastles and weather decks	5,4 (0·72)
Elsewhere	3,3 (0·44)

Aft of 0,12L from the fore perpendicular:—

$h = 1{,}2 + 2{,}04E$ metres ($h = 4 + 6{\cdot}7E$ ft), and is not to be less than 1,2 m (4 ft) nor greater than 1,5 m (5 ft).

$$\text{where } E = \frac{0{,}0914 + 0{,}003L}{D-d} - 0{,}15$$

$$\left(E = \frac{0{\cdot}3 + 0{\cdot}003L}{D-d} - 0{\cdot}15 \text{ British}\right)$$

Between 0,075L and 0,12L from forward, h is 1,5 m (5 ft). In the forward 0,075L, including forecastle decks, h is 1,8 m (6 ft). For decks above the uppermost continuous deck, h obtained from the above formulæ can be successively reduced by 0,310 m (1·02 ft) for each deck, to a minimum of 0,450 m (1·48 ft).

807 If the beams carry hanging cargo, such as chilled beef, the modulus determined from 806 is to be increased by 50 per cent if the height of the 'tween deck below is 2,6 m (8·5 ft) or less and 100 per cent if the height is 3,2 m (10·5 ft) (with intermediate heights in proportion), but the modulus need not exceed that derived from 810 for a 2,6 m (8·5 ft) 'tween deck height above. No increase is required if the modulus derived from 810 is less than that derived from 806.

Carriage of Timber on Weather Decks

808 Where timber load lines are to be assigned the modulus obtained from 806 is to be increased by 20 per cent for ships having a breadth up to and including 16,0 m (52·5 ft). No increase is required for breadths of 21,5 m (70·5 ft) and over. The increase at intermediate breadths is to be obtained by interpolation. In single deck ships the modulus is to be increased by 20 per cent irrespective of the breadth. (A ship with topside tanks is not considered as a single deck ship.)

Cargo and Accommodation Decks

809 The section modulus of cargo and accommodation deck beams is not to be less than:—

$$\frac{I}{y} = \frac{K_1 K_4 d D}{1000} + \frac{3{,}88 h S^2 s}{1000} \text{ cm}^3$$

$$\left(\frac{I}{y} = \frac{K_1 K_4 d D}{1000} + \frac{0{\cdot}17 h S^2 s}{1000} \text{ in}^3\right)$$

K_1 is a constant obtained from Table D 8.1 and K_4 is given in Table D 8.4:—

TABLE D 8.4

TYPE OF DECK	K_4
Cargo	40 (3)
Accommodation	53 (4)

For cargo decks h is the mean height of the 'tween deck in metres (feet). Where insulation is fitted underneath a deck, the 'tween deck height may be reduced by 150 mm (6 in).

For decks under accommodation spaces h is 1,2 m (4 ft). For decks above the uppermost continuous deck this value can be successively reduced by 0,31 m (1·02 ft) for each deck to a minimum of 0,45 m (1·48 ft).

Decks under ship store spaces other than refrigerated stores can, in general, be based on h equal to 2,0 m (6·56 ft). For engine room stores or flats h is 2,6 m (8·5 ft).

810 If cargo deck beams carry hanging cargo such as chilled beef and may be simultaneously loaded above with cargo, the modulus is to be determined from 809 with h increased by 0,76 m (2·5 ft) if the height of the 'tween deck below is 2,6 m (8·5 ft) or less and 2,29 m (7·5 ft) if the height is 3,8 m (12·5 ft) (with intermediate heights in proportion). A similar addition is to be made, if appropriate, to accommodation deck beams.

Fork Lift Trucks

811 Where fork lift trucks are to be used, the section modulus of the beams is not to be less than:—

$$\frac{I}{y} = \frac{375 K_5 TS}{1000} + \frac{1{,}25 K_6 h S^2 s}{1000} \text{ cm}^3 \text{ (in}^3)$$

or that derived from 809 or 810 if appropriate, whichever is the greater,

where K_5 and K_6 are coefficients obtained from Table D 8.5,

T = total weight of truck and its load, in tonnes (tons).

TABLE D 8.5

DISTANCE BETWEEN LOAD BEARING WHEELS / BEAM SPAN	K_5	K_6
0,1	15,4 (0·291)	1,89 (0·083)
0,2	14,6 (0·276)	1,845 (0·081)
0,3	13,35 (0·253)	1,730 (0·076)
0,4	11,8 (0·223)	1,55 (0·068)
0,5	10,1 (0·191)	1,30 (0·057)
0,6	8,46 (0·160)	0,98 (0·043)
0,7	7,78 (0·147)	0,66 (0·029)
0,8	6,77 (0·128)	0,343 (0·015)
0,9	4,28 (0·081)	0,091 (0·004)

Beam Knees and their Attachment

812 The scantlings of beam knees and their welded attachment are to be in accordance with D 727 to D 735.

813 In ships having more than three tiers of beams and where large areas of deck are arranged for accommodation, or where particular conditions of loading are contemplated, the requirements for beam knees will be considered.

814 The attachment of half beams to hatch side coamings and casings is given in Table D 32.1.

Cross-references

815 For strong hatch end beams and deck transverses, *see* D 13.

For strengthening in machinery spaces, *see* D 21.

For cantilevers, *see* D 15.

Section 9

DOUBLE BOTTOMS

Symbols

901 L = length of ship, in metres (feet).

B = moulded breadth, in metres (feet).

d = moulded draught, in metres (feet).

s = spacing of frames or longitudinals, in mm (in).

D_{DB} = minimum depth of centre girder, in mm (in). *See* 904.

Application

902 This section provides for longitudinal or transverse framing in the double bottom but for ships exceeding 120 m (395 ft) in length, longitudinal framing is, in general, to be adopted. Longitudinal framing is to be adopted when a notation regarding the carriage of heavy or ore cargoes is to be assigned.

903 Where specified cargo holds may be empty in the loaded condition, *see* 940 to 948.

Centre Girder

904 The depth of the centre girder is not to be less than given by:—

$$D_{DB} = \frac{1000B}{36} + 205\sqrt{d} \ \text{mm} \qquad (1)$$

$$\left(D_{DB} = \frac{B}{3} + 4{\cdot}5\sqrt{d} \ \text{in}\right)$$

The thickness is not to be less than:—

$$\left.\begin{array}{l} t = 0{,}008D_{DB} + 4 \text{ mm} \\ (t = 0{\cdot}008D_{DB} + 0{\cdot}15 \text{ in}) \end{array}\right\} \text{for } 0{,}4L \text{ amidships} \qquad (2)$$

and
$$\left.\begin{array}{l} t = 0{,}008D_{DB} + 2 \text{ mm} \\ (t = 0{\cdot}008D_{DB} + 0{\cdot}08 \text{ in}) \end{array}\right\} \text{for } 0{,}1L \text{ at ends} \qquad (3)$$

For duct keels, *see* 931.

Inner Bottom Plating

905 The thickness of the inner bottom plating throughout the holds is not to be less than:—

$$\left.\begin{array}{l} t = 0{,}001\,36\sqrt[4]{Ld}\,(s + 660) \text{ mm} \\ (t = 0{\cdot}000\,75\sqrt[4]{Ld}\,(s + 26) \text{ in}) \end{array}\right\} \text{for } 0{,}4L \text{ amidships} \qquad (1)$$

and

$$\left.\begin{array}{l} t = 0{,}001\,27\sqrt[4]{Ld}\,(s + 660) \text{ mm} \\ (t = 0{\cdot}000\,70\sqrt[4]{Ld}\,(s + 26) \text{ in}) \end{array}\right\} \text{for } 0{,}1L \text{ at ends} \qquad (2)$$

If a notation regarding the carriage of "Heavy Cargoes" or "Ore Cargoes" is to be assigned the thickness derived from the above is to be increased by 5 mm (0·20 in) but is not to be less than:—

$$t = \frac{s\sqrt{W}}{220} \text{ mm} \qquad \left(t = 0{\cdot}015\, s\sqrt{W} \text{ in}\right) \qquad (3)$$

W = tank top loading in tonne/m² (ton/ft²) and calculated as:—

$$\frac{\text{Weight of cargo in the hold}}{\text{Volume of the hold}} \times \begin{array}{c}\text{Head from tank top to} \\ \text{deck line at centre}\end{array}$$

The thickness of the inner bottom plating as determined above is to be increased by 2 mm (0·08 in) under the hatchways if no ceiling is fitted and no increase has been made for heavy or ore cargoes.

For recommendations for thickness of plating when fork lift trucks are to be used, *see* D 418.

906 Where the double bottom tanks are common with wing ballast tanks or cofferdams the thickness of the inner bottom plating is to be not less than required by D 1919 for the crown of a tank.

907 If cargo is to be regularly discharged by grabs from ships not having "Heavy Cargoes" or "Ore Cargoes" notation it is recommended that double ceiling be fitted or the thickness of the plating increased 5 mm (0·20 in) and fitted with a flush surface.

Margin Plate

908 A margin plate, if fitted, is to have a thickness throughout 20 per cent greater than required for inner bottom plating amidships. *See* 905.

909 In passenger ships, the inner bottom plating is to be continued out to the ship's side in such a manner as to protect the bottom to the turn of bilge. Such protection will be satisfactory if the line of intersection of the outer edge of the margin plate with the bilge plating is not lower at any

part than a horizontal plane passing through the point of intersection with the frame line amidships of a transverse diagonal line inclined at 25 degrees to the base line and cutting it at a point one half the ship's moulded breadth from the middle line.

TRANSVERSE FRAMING

Plate Floors

910 Plate floors are to be fitted at every frame in the engine room and forward as required by D 10. They are also to be fitted under the boiler bearers, bulkheads, toes of brackets to deep tank bulkhead stiffeners and in way of any change in depth of double bottom. Partial plate floors are to be fitted under the thrust seating. Floors of increased thickness are to be arranged in way of shaft brackets.

911 In ships from which cargo is to be regularly discharged by grabs, it is recommended that plate floors be fitted at every frame.

912 Except as required by 910, plate floors may be spaced not more than 3,05 m (10 ft) apart, and the shell and inner bottom plating between these floors is to be supported by bracket floors.

913 The thickness of non-watertight plate floors is not to be less than:—

$$t = 0{,}008D_{DB} + 1 \text{ mm} \quad (t = 0{\cdot}008D_{DB} + 0{\cdot}04 \text{ in}) \quad \text{but need not exceed } 15 \text{ mm } (0{\cdot}59 \text{ in}).$$

914 Watertight or strengthened floors are to be fitted below, or in the vicinity of, watertight bulkheads and their thickness is to be 2 mm (0·08 in) greater than given in 913 for non-watertight floors, but need not exceed 15 mm (0·59 in).

If the depth of the centre girder exceeds 915 mm (36 in) the floors are to be fitted with stiffeners spaced not more than 915 mm (36 in) and having a section modulus not less than:—

$$\frac{I}{y} = \frac{D_{DB_1}{}^2 \times h_{DB} \times s_{DB}}{185 \times 10^6} \text{ cm}^3$$

$$\left(\frac{I}{y} = \frac{D_{DB_1}{}^2 \times h_{DB} \times s_{DB}}{600\,000} \text{ in}^3\right)$$

where D_{DB_1} = actual depth of centre girder, in mm (in).

h_{DB} = head from top of inner bottom to top of overflow pipe, in metres (feet).

s_{DB} = stiffener spacing, in mm (in).

The ends of the stiffeners are to be sniped.

915 Where the double bottom tanks are common with wing ballast tanks or cofferdams the scantlings of watertight floors are not to be less than required by D 19 for a tank bulkhead.

Bracket Floors

916 The bottom frames are to have a section modulus not less than:—

$$\frac{I}{y} = 215S_1sd \times 10^{-4} \text{ cm}^3$$

$$\left(\frac{I}{y} = 3{\cdot}1S_1sd \times 10^{-3} \text{ in}^3\right)$$

where S_1 is unsupported span, in metres (feet).

The reversed frames are to have a section modulus not less than 85 per cent of that given above for the bottom frames and the unsupported span of bottom and reversed frames is not to exceed 2,5 m (8·2 ft).

917 The breadth of the brackets attaching the frames and the reversed frames to the centre girder and margin plate is to be three-quarters of the depth of the centre girder; the brackets are to be flanged on the unsupported edge and are to have the same thickness as the plate floors.

918 Where struts are fitted to reduce the unsupported span of the frames and reversed frames they are to have a cross sectional area not less than:—

$$A = 0{,}32\ Z \text{ cm}^2 \text{ for } Z \leqslant 83{,}5$$

$$(A = 0{\cdot}8\ Z \text{ in}^2 \text{ for } Z \leqslant 5{\cdot}1)$$

$$A = 23{,}2 + \frac{Z}{25} \text{ cm}^2 \text{ for } Z > 83{,}5$$

$$\left(A = 3{\cdot}6 + \frac{Z}{10} \text{ in}^2 \text{ for } Z > 5{\cdot}1\right)$$

where $Z = \frac{I}{y}$ of bottom frame determined from 916.

Side Girders

919 One side girder is to be fitted when the breadth B does not exceed 20 m (65·6 ft), and for greater breadths two girders are to be fitted on each side of the centre line. The girders are to extend as far forward and aft as practicable and are to have a thickness not less than:—

$$t = 0{,}008D_{DB} + 1 \text{ mm}$$

$$(t = 0{\cdot}008D_{DB} + 0{\cdot}04 \text{ in})$$

Vertical stiffeners are to be fitted at every bracket floor and are to have a depth not less than the depth of the reversed frame, or 150 mm (6 in), whichever is the greater. The thickness is to be as required for the girder.

For side girders in the forward 0,3L, *see* D 10.

Watertight side girders are to have a thickness 1 mm (0·04 in) greater than given above.

920 In the machinery space and thrust recess, the number and disposition of the side girders are to be such as to support the machinery effectively and to secure the necessary rigidity of structure.

LONGITUDINAL FRAMING

921 Where longitudinal framing is adopted in the double bottom (*see* 902) the scantlings of the longitudinals are to be determined from D 606 to D 610. Plate girders are to have a thickness determined from 927.

Plate Floors

922 Plate floors are to be fitted at every frame under the main engines and the foremost shaft tunnel bearing and at alternate frames outboard of the engine seating. They are also to be fitted under boiler bearers, bulkheads and the toes of brackets of deep tank bulkhead stiffeners.

Elsewhere, the spacing of the floors is not to exceed 3,7 m (12·1 ft), except when a notation regarding the carriage of heavy or ore cargoes is to be assigned. In this case, the spacing of floors is not to exceed 2,5 m (8·2 ft).

For spacing of floors in the forward 0,3L, *see* D 10.

923 The thickness of plate floors is not to be less than:—

$$t = 0{,}009D_{DB} + 1 \text{ mm}$$
$$(t = 0{\cdot}009D_{DB} + 0{\cdot}04 \text{ in})$$

The thickness need not be greater than 15 mm (0·59 in) but the ratio between the depth of the double bottom and the thickness of floor is not to exceed 130. This ratio may, however, be exceeded if suitable additional stiffening is fitted.

924 Vertical stiffeners are to be fitted at each longitudinal, having a depth not less than 150 mm (6 in) and a thickness equal to the thickness of the floors.

925 For watertight floors the plate thickness is not to be less than the greater of the thicknesses determined from 914 and 923. The section modulus of the stiffeners is not to be less than required by D 1908 with ω_1 and ω_2 taken equal to 1,0 and e_1 and e_2 equal to 0, or as required by 924, whichever is the greater. The stiffeners are to be connected to the inner bottom and bottom longitudinals.

926 Between plate floors, transverse brackets having a thickness not less than $0{\cdot}009D_{DB}$ mm (in) are to be fitted extending from the centre girder and margin plate to the adjacent longitudinal. The brackets, which are to be suitably stiffened at the edge, are to be fitted at every frame at the margin plate and those at the centre girder are to be spaced not more than 1,25 m (4·1 ft).

For duct keels, *see* 931.

Side Girders

927 One side girder is to be fitted where the breadth B exceeds 14 m (46 ft) and two girders are to be fitted on each side of the centre line where B exceeds 21 m (69 ft). When a notation regarding the carriage of heavy or ore cargoes is to be assigned the spacing of side girders is not to exceed 3,7 m (12·1 ft).

The girders are to extend as far forward and aft as practicable and are to have a thickness not less than:—

$$t = 0{,}0075D_{DB} + 1 \text{ mm}$$
$$(t = 0{\cdot}0075D_{DB} + 0{\cdot}04 \text{ in})$$

Watertight side girders are to have a thickness 1 mm (0·04 in) greater than given above and stiffeners are to be in accordance with 914.

For side girders in the forward 0,3L, *see* D 10.

928 The longitudinal girders under the main machinery are to extend for the full length of the machinery space and are to be carried aft to support the foremost shaft tunnel bearing. This extension abaft the after engine room bulkhead is to be at least three transverse frame spaces. Forward of the engine room the girders are to be tapered off over three transverse frame spaces and are to be efficiently scarphed into the longitudinal framing system.

929 A vertical stiffener is to be arranged midway between floors when these are spaced two or more frame spaces apart. The stiffeners are to have a depth not less than 100 mm (4 in) and a thickness equal to the girder thickness.

930 Where, at the ends of the ship, the longitudinal system of framing is replaced by a transverse system, adequate arrangements are to be made to avoid abrupt discontinuities.

GENERAL

Duct Keels

931 Where duct keels are arranged the side plates are to have a thickness not less than 1 mm (0·04 in) greater than required by 919. The sides are, in general, not to be spaced more than 1,83 m (6 ft) apart. The inner bottom and bottom shell within the duct keel are to be suitably stiffened, and continuity of floors is to be maintained.

Increased Thicknesses in Engine Rooms

932 In engine rooms the thickness of the inner bottom plating is not to be less than:—

$$t = 0{,}0015\sqrt[4]{Ld}\,(s + 660) \text{ mm}$$
$$(t = 0{\cdot}000\,85\sqrt[4]{Ld}\,(s + 26) \text{ in})$$

Manholes and Lightening Holes

933 Sufficient holes are to be cut in the inner bottom floors and side girders, to provide adequate ventilation and

access to all parts of the double bottom. The edges of all holes are to be smooth. The size of opening should not, in general, exceed 50 per cent of the double bottom depth, unless edge reinforcement is provided. In way of ends of floors and fore and aft girders at transverse bulkheads, the number and size of holes is to be kept to a minimum, and the openings are to be circular or elliptical. Edge stiffening may be required in these positions. The requirements of 945 and 947 regarding area of floor and girder are also to be complied with where applicable.

934 Where manhole covers are attached by bolts to the inner bottom plating, doubling rings are to be fitted to take the fastenings of the covers. Manhole covers which project above the inner bottom plating are to be adequately protected.

Ships Loading and Discharging Aground

935 It is recommended that the bottoms of ships intended to load or discharge aground be additionally strengthened in order to withstand the stresses to which they may be subjected.

Longitudinal Subdivision

936 If oil fuel is to be carried in double bottoms, holes are not to be cut in the centre girder except in the forward and after tanks, and elsewhere where tanks are narrow due to subdivision. When timber load lines are to be assigned, double bottom tanks within the midship half length are to have adequate longitudinal subdivision.

The centre girder need not be tested.

Pumping and Drainage

937 The arrangements are to be in accordance with the requirements of Chapter E. Provision is to be made for the free passage of air and water from all parts of the tanks to the air pipes and suctions, taking into account the pumping rates required.

Testing

938 Each compartment is to be tested on completion with a head of water representing the maximum pressure which could be experienced in service. Alternatively, air testing in accordance with D 5202, excluding the structural test, may be carried out.

Cross-references

939 For additional stiffening under heels of pillars, *see* D 1408.

For strengthening of bottom forward, *see* D 10.

For compartments carrying oil fuel or lubricating oil, *see* D 1926 and D 1931.

For reserve feed water compartments, *see* E 710.

CARRIAGE OF HEAVY OR ORE CARGOES WITH SPECIFIED OR ALTERNATE HOLDS EMPTY

940 Where a notation regarding the carriage of heavy or ore cargoes, with specified or alternate holds empty, is to be assigned, the following requirements are to be complied with. Alternatively, the scantlings may be assessed by direct calculation using an agreed procedure.

Symbols

941 w = double bottom loading, in tonne/m² (ton/ft²), and is to be taken as:—

$$W - 0{,}68d \quad \left(W - \frac{d}{52{\cdot}5}\ \text{British}\right)$$

for full holds, and $1{,}02d$ $\left(\frac{d}{35}\ \text{British}\right)$ for empty holds, where W is as defined in 905.

b = span of floors, in metres (feet), measured to intersection of hopper side or ship's side, and tank top.

l = length of hold, in metres (feet), measured between bulkhead stools, where fitted, at the level of the tanktop on the centre-line.

S_1 = spacing of floors, in metres (feet).

S_2 = half the distance between girders adjacent to the girder in question, in metres (feet).

$\alpha = \frac{l}{b}$ and is not to be taken as less than 0,5 nor greater than 1,5.

$\alpha_c = 1{,}15 - 0{,}275k_1$

$$k_1 = \frac{p^3}{p^3 + 305q^2\alpha} \quad \left(k_1 = \frac{p^3}{p^3 + 1000q^2\alpha}\ \text{British}\right)$$

Where there is no hopper side tank, k_1 is to be taken as zero and if the slope of the hopper side is less than 30° to the horizontal the value of k_1 will be considered.

$k_2 = k_1\,(0{,}205 - 0{,}024\alpha) + 0{,}312\alpha + 0{,}034$ when $0{,}5 < \alpha \leqslant 1{,}0$

or $k_1\,(0{,}349 - 0{,}168\alpha) + 0{,}168\alpha + 0{,}178$ when $1{,}0 < \alpha \leqslant 1{,}5$

$k_3 = 0{,}192\alpha + 0{,}148 - k_1(0{,}192\alpha - 0{,}092)$ when $0{,}5 < \alpha \leqslant 1{,}0$

or $0{,}04\alpha + 0{,}30 - k_1\,(0{,}04\alpha + 0{,}06)$ when $1{,}0 < \alpha \leqslant 1{,}5$

p = girth of hopper side tank, including hopper side and double bottom height, in metres (feet).

q = depth of double bottom, in metres (feet). Where the tank top slopes from the side to the centre-line, q is to be taken as the least depth plus three-quarters of the rise.

NOTE:—q may be taken initially as derived from 904. Where this height of double bottom is increased to comply with 942 or 943 successive calculations will be required.

t = thickness of inner bottom plating (*see* 905 and 906) or bottom shell plating, whichever is the least, in mm (inches). Where high tensile steel is fitted the equivalent mild steel thickness is to be used.

NOTE:—The proportion of the double bottom load carried by the transverse bulkhead is:—

$$\frac{k_3}{k_2 \frac{l}{b} + k_3}$$

The actual value of $\frac{l}{b}$ should be used ignoring the upper and lower limits in the definition of α.

942 The depth of centre girder is not to be less than required by 904 or the following, whichever is the greater:—

$$\frac{cwb^2P}{t} \text{ mm (in)}$$

where $P = 0{,}054\alpha - k_1\,(0{,}0349\alpha - 0{,}0134) - \frac{\delta}{100}$

$$\left.\begin{array}{l} c = 89 \\ \delta = 0 \end{array}\right\} \text{ when } \alpha \geqslant \alpha_c$$

$$\left.\begin{array}{l} c = 114{,}5 \\ \delta = 5{,}55k_1\,(\alpha - 0{,}6)^2 + 5{,}63\,(\alpha - 0{,}7)^2(1 - k_1) \end{array}\right\} \text{ when } \alpha < \alpha_c$$

or in British units:—

$$\left.\begin{array}{l} c = 0{\cdot}14 \\ \delta = 0 \end{array}\right\} \text{ when } \alpha \geqslant \alpha_c$$

$$\left.\begin{array}{l} c = 0{\cdot}18 \\ \delta = 5{\cdot}55k_1(\alpha - 0{\cdot}6)^2 + 5{\cdot}63(\alpha - 0{\cdot}7)^2(1 - k_1) \end{array}\right\} \text{ when } \alpha < \alpha_c$$

943 The depth of double bottom is to be such that the depth of floor at the hopper side tank is not less than:—

$$\frac{89\,wb^2k_1}{t}\left(\frac{0{,}0892\,\alpha^3}{0{,}283 + \alpha^3}\right) \text{ mm}$$

$$\left(\frac{0{\cdot}14\,wb^2k_1}{t}\left(\frac{0{\cdot}0892\,\alpha^3}{0{\cdot}283 + \alpha^3}\right) \text{ in}\right)$$

944 When the depth of the hopper side tank derived from 943 exceeds that required by 942 the inner bottom plating may be sloped, but the height at the centreline is not to be less than required by 904 or 942. Alternatively, the double bottom may have the height required by 904 or 942 and the thickness of the inner bottom plating or bottom shell (or both) is to be increased in way of the hopper side tank so that the requirement of 943, using the increased thickness, is satisfied. The increased thickness is to extend 610 mm (24 in) outboard of the hopper side knuckle and $\frac{b}{10}$ metres (ft) inboard of the knuckle and over the length of the hold concerned.

945 Plate floors are to be spaced not more than 2,5 m (8·2 ft) and are to have a thickness giving a net sectional area (excluding openings) at the hopper side of:—

$0{,}89S_1wbk_2$ cm² ($0{\cdot}14S_1wbk_2$ in²) for the middle half length of the hold.

$0{,}635S_1wbk_2$ cm² ($0{\cdot}10S_1wbk_2$ in²) for the quarter-length of the hold at each end.

The net sectional area (excluding openings) at any point y metres (feet) from the centreline, is not to be less than $\frac{2y}{b}$ times the required area at the hopper side. The thickness is not to be less than required by 923.

946 If intermediate partial floors extending from the hopper side tank to the next plate longitudinal are fitted, they are to have a thickness not less than $0{,}009D_{DB}$ mm (in) and 75 per cent of their thickness may be taken into account in assessing the area of floors required by 945.

947 Plate girders are to be spaced not more than:—

$$1{,}4 + \frac{L_1}{180} \text{ m}$$

$$\left(4{\cdot}6 + \frac{L_1}{180} \text{ ft}\right)$$

where L_1 = length of ship, in metres (feet), but not to be taken as greater than 215 m (705 ft).

They are to have a thickness giving a net sectional area (excluding openings) at the bulkheads of:—

$0{,}89S_2wbk_3$ cm² ($0{\cdot}14S_2wbk_3$ in²) for the middle half-breadth of the hold,

$0{,}635S_2wbk_3$ cm² ($0{\cdot}10S_2wbk_3$ in²) for the quarter-breadth of the hold at each side.

The net sectional area (excluding openings) at any point x metres (feet) forward or aft of the mid-length of the hold is not to be less than $\frac{2x}{l}$ times the required area at the bulkheads. The thickness is not to be less than required by 927.

948 If intermediate partial plate girders extending from the bulkhead to the next plate floor are fitted, they are to have a thickness not less than $0{,}009D_{DB}$ mm (in) and 75 per cent of their thickness may be taken into account in assessing the area of girders required by 947.

Section 10

STRENGTHENING OF BOTTOM FORWARD

Symbols

1001 L_1 = length of ship, in metres (feet), but need not exceed 215 m (705 ft).

C_b = block coefficient at load draught.

s = frame or longitudinal spacing, in mm (inches).

s_b = Standard frame spacing in mm (inches) i.e. (i) forward of 0,2L from fore perpendicular:—as required by D 705 and D 706,

(ii) aft of 0,2L from fore perpendicular:—

$$\frac{L_1}{0,6} + 510 \text{ mm} \qquad \left(\frac{L_1}{50} + 20 \text{ in}\right)$$

Extent

1002 The bottom forward is to be strengthened for the following extent except when the ship is designed so that a ballast draught forward of $0,04L_1$ can be achieved:—

C_b of 0,70 or under — between 0,05L and 0,3L from forward

C_b of 0,80 or over — between 0,05L and 0,25L from forward

At intermediate C_b, the extent may be obtained by interpolation.

Bottom Framed Longitudinally

1003 (a) Longitudinal spacing is to be in accordance with D 704 and D 705.

(b) Plate floors are to be fitted on alternate frames and are to have scantlings not less than required by D 923.

(c) Bottom longitudinals are to have scantlings in accordance with D 606 using a minimum span of 1,85 m (6·1 ft).

(d) Side girders are to be fitted not more than 2,1 m (6·9 ft) apart and are to have scantlings required by D 927.

Bottom Framed Transversely

1004 (a) Frames are to be spaced in accordance with D 704, D 705 and D 706.

(b) Plate floors are to be fitted at every frame and are to have scantlings not less than required by D 913.

(c) Side girders are to be fitted not more than 2,2 m (7·25 ft) apart and are to have scantlings required by D 919.

(d) Half height side girders are to be fitted not more than 1,1 m (3·63 ft) apart and are to have scantlings not less than required by D 919. They are to extend as far forward as practicable.

Shell Plating

1005 When the ship is designed so that a ballast draught forward of $0,04L_1$ can be achieved, no increase in the thickness of shell plating is required.

When the ballast draught forward is $0,03L_1$ or less, the thickness of the strakes wholly or partly covering the flat of bottom within the region defined in 1002 is not to be less than:—

$$t = 0,092L_1 + 7\sqrt{\frac{s}{s_b}} \text{ mm}$$

$$\left(t = 0{\cdot}0011L_1 + 0{\cdot}276\sqrt{\frac{s}{s_b}} \text{ in}\right)$$

For intermediate draughts the thickness is to be obtained by interpolation between the above value and the tapered thickness. For this purpose, the nominal thickness at 0,2L from amidships for a ballast draught of $0,04L_1$ may be taken as that required by D 504 (a) or (b) as appropriate, using the minimum spacing of

$$\frac{L_1}{0,6} + 510 \text{ mm} \qquad \left(\frac{L_1}{50} + 20 \text{ in}\right)$$

(d in the formulæ being the load draught) and if the spacing differs from that given in 1001 the tapered thickness is to be corrected in the ratio $\sqrt{\frac{s}{s_b}}$.

The midship thickness of the strakes referred to above is to be carried forward to the increased plating.

The thickness of the keel plate is not to be less than that of the adjoining plating.

1006 If intermediate stiffening is fitted, the thickness of the bottom shell plating may be 80 per cent of that required by 1005 but is not to be less than the normal taper thickness.

General

1007 Floors and girders are to be connected to the shell by continuous welding and drain holes are to be kept to a minimum.

Section 11

PANTING

Symbols

1101 L = length of ship in metres (feet).

L_1 = length of ship, in metres (feet), but need not be taken greater than 215 m (705 ft).

B_1 = moulded breadth, in metres (feet), but need not be taken greater than 32 m (105 ft).

l = vertical spacing, in metres (feet), of stringers and panting beams.

h = vertical distance, in metres (feet), from the stringers to the line of the deck at side amidships.

s = horizontal spacing of beams, in metres (feet).

S = span of beams, in metres (feet), measured from the flange of the stringer, or from half the distance between the edge of the stringer and the inboard side of the framing when the stringer is unflanged, to the centreline support, or to the opposite span point where no centreline support is provided.

General

1102 The structure is to be strengthened to resist panting for 0,15L from the fore end, and abaft the after peak bulkhead.

Forward of the Collision Bulkhead

1103 Tiers of beams to be spaced not more than 2 m (6·56 ft) apart vertically are to be fitted to alternate frames in the fore peak tank, or below the lowest deck above the water-line if the peak tank is small, and are each to have a cross-sectional area not less than:—

$$A = 2{,}5B_1 - \frac{L_1}{25}\ \text{cm}^2 \qquad \left(A = 0{\cdot}118B_1 - \frac{L_1}{530}\ \text{in}^2\right) \qquad (1)$$

In addition, the least moment of inertia of any beam is not to be less than:—

$$I = lhsS^2\ \text{cm}^4 \qquad \left(I = \frac{lhsS^2}{15\,820}\ \text{in}^4\right) \qquad (2)$$

Alternatively, perforated flats may be fitted in lieu of panting beams. The arrangement and scantlings of these flats are to be as required by D 5417 and D 5439 (1).

1104 In general, the tiers of beams are to be supported at the centreline by a partial wash bulkhead or pillars.

1105 The beams are to be connected to the side frames by brackets having a depth below the stringer, measured along the inboard side of the frame, not less than

$$\frac{150A}{t}\ \text{mm} \qquad \left(\frac{1{\cdot}5A}{t}\ \text{in}\right)$$

where A = sectional area of beam, in cm² (in²), obtained from 1103,

t = thickness of bracket, in mm (inches), and is to be not less than the thickness of stringer plate (*see* 1106).

In no case is the cross-sectional area through the throat of the bracket to be less than A.

Frames to which a beam is not fitted are to be attached to the stringer plate by brackets having the same thickness as the stringer (*see* 1106) and having a depth measured at the shell of one half the width of the stringer plate.

1106 Stringer plates attached to the shell are to be fitted at each tier of beams, and are to have scantlings not less than:—

$$\text{Width} = 3{,}3L + 400\ \text{mm}$$

$$\left(\text{Width} = \frac{L}{25{\cdot}3} + 15{\cdot}75\ \text{in}\right)$$

$$\text{Thickness} = \frac{2{,}5L}{100} + 6\ \text{mm}$$

$$\left(\text{Thickness} = \frac{3L}{10\,000} + 0{\cdot}236\ \text{in}\right)$$

Abaft the Collision Bulkhead

1107 Intercostal side stringers having the same depth as the frames, a face flat of width L mm $\left(\frac{L}{83{\cdot}5}\ \text{in}\right)$ and the thickness required by 1106, are to be fitted in line with those forward of the collision bulkhead and are to extend aft for the distance defined in 1102; they are to be attached to the shell by welding having a weld factor of 0,35 (0·50). *See* Notes—Table D 32.1.

The stringers may be omitted provided the shell plating is increased by 15 per cent for vessels having a length up to and including 150 m (492 ft), and 5 per cent where the length is 215 m (705 ft) and above. For intermediate lengths, the percentage may be obtained by interpolation.

For hold frames having spans in excess of 9 m (29·5 ft), *see* D 708.

1108 Tank side brackets are to be fitted to all frames and the strength of the attachment of the frames to the tank side brackets is to be increased by 20 per cent above the requirements of D 733.

Abaft the After Peak Bulkhead

1109 The structure is to be efficiently stiffened by deep floors and tiers of beams in association with stringers, having scantlings required by 1103 and 1106 respectively, except that they may be spaced 2,5 m (8·2 ft) apart vertically.

In twin screw ships the frames abaft the propeller brackets and up to the lowest deck are to be attached to the shell plating by welding having a weld factor of 0,44 (0·63). *See* Notes—Table D 32.1.

Special arrangements may be required in single screw ships of high speed.

If, on account of the ship's form, the unsupported length of frames exceeds 2,5 m (8·2 ft), additional stiffening may be required.

For details of welding in after peak structure, *see* Table D 32.1 and D 5520.

Deep 'Tween Decks

1110 In ships having deep 'tween decks additional intercostal side stringers may be required or the thickness of the shell plating is to be suitably increased.

Cross-references

1111 For framing and webs in peaks, *see* D 713 and D 714.

For structure in bulbous bows, *see* D 5441.

Section 12

STEMS AND STERNFRAMES

Symbols

1201 L = length of ship, in metres (feet).

L_1 = length of ship, in metres (feet), but need not be taken as greater than 215 m (705 ft).

d = moulded draught, in metres (feet).

V = maximum service speed, in knots, with the ship in the loaded condition.

Materials

1202 Steel castings are to comply with the requirements of P 5.

1203 Forgings are to comply with the requirements of P 6.

STEMS

1204 Bar stems are to have scantlings not less than:—

$$A = 1{,}6L - 32 \text{ cm}^2$$
$$(A = 0{\cdot}076L - 5 \text{ in}^2)$$

where A = cross sectional area of the stem bar in cm² (in²).

Above the load waterline the dimensions may be gradually tapered to the stem head where the area may be reduced by 25 per cent.

1205 Where the stem is constructed of shaped plates, the thickness of the plates below the load waterline is to be not less than:—

$$t = 0{,}083\ L_1 + 5 \text{ mm}$$
$$\left(t = \frac{L_1}{1000} + 0{\cdot}2 \text{ in}\right)$$

where t = thickness of plating, in mm (in).

Above the load waterline the thickness may be gradually tapered to the stem head where it may have the same thickness as the shell at ends (*see* D 508).

1206 Plate stems are to be supported by horizontal webs between the decks and below the lowest deck; the unsupported length of stem plates is not to exceed 1,5 m (5 ft).

Where the curvature of the plate is large a centreline web may be required.

For strengthening of plate stems for navigation in ice, *see* D 24.

For bulbous bows, *see* D 54.

STERNFRAMES

1207 Sternframes may be cast or forged or may be fabricated from plate.

Cast steel and fabricated sternframes are to be strengthened at intervals by transverse webs. In castings, sudden changes of section or possible constrictions to the flow of metal during casting are to be avoided. All fillets are to have adequate radii which should not, in general, be less than 50 to 75 mm (1·9 to 2·9 in) depending upon the size of the casting.

1208 All sternframes are to be efficiently attached to the ship structure and the lower part of the sternframe is to be extended forward to provide an efficient connection to the flat plate keel.

Propeller Posts

1209 The scantlings of propeller posts are to be not less than:—

(i) **Fabricated propeller post**

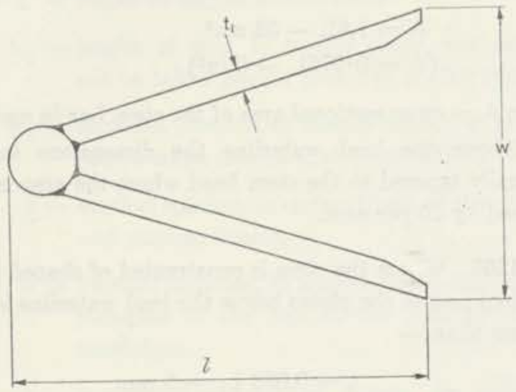


FIG. D 12.1

$l = 200\sqrt{d}$ mm ($l = 4{\cdot}33\sqrt{d}$ in)
$w = 140\sqrt{d}$ mm ($w = 3{\cdot}03\sqrt{d}$ in)
$t_1 = 12\sqrt{d}$ mm ($t_1 = 0{\cdot}26\sqrt{d}$ in)

(ii) **Cast propeller post**

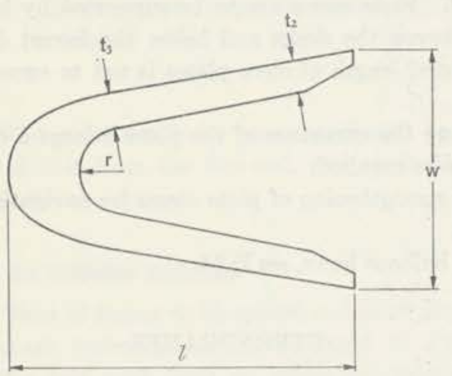


FIG. D 12.2

$l = 165\sqrt{d}$ mm ($l = 3{\cdot}57\sqrt{d}$ in)
$w = 115\sqrt{d}$ mm ($w = 2{\cdot}49\sqrt{d}$ in)
$t_2 = 12\sqrt{d}$ mm ($t_2 = 0{\cdot}26\sqrt{d}$ in)
(minimum 19 mm) (minimum 0·75 in)
$t_3 = 16\sqrt{d}$ mm ($t_3 = 0{\cdot}346\sqrt{d}$ in)
(minimum 25,5 mm) (minimum 1 in)
$r = 20\sqrt{d}$ mm ($r = 0{\cdot}433\sqrt{d}$ in)

In cast propeller posts the thickness of transverse webs is not to be less than $0{,}65t_2$ but need not exceed 38 mm (1·5 in).

Connection

1210 Rudder posts are to be connected to a transom floor of the same depth as that required for a double bottom floor and having a thickness 2,5 mm (0·10 in) greater than that required by D 913.

Stern Frames on Twin Screw Ships

1211 The dimensions of rudder posts which are built integral with the hull of twin screw ships are not to be less than as given below:—

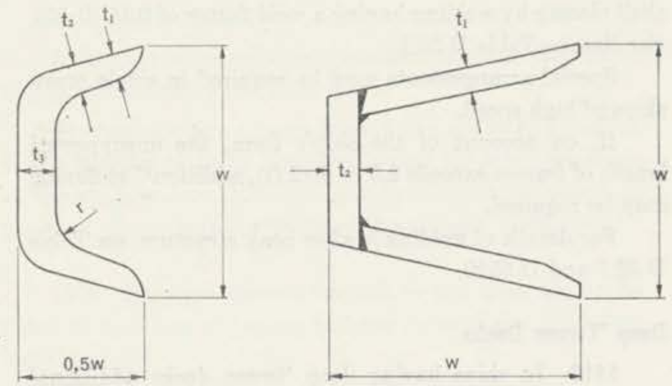


FIG. D 12.3

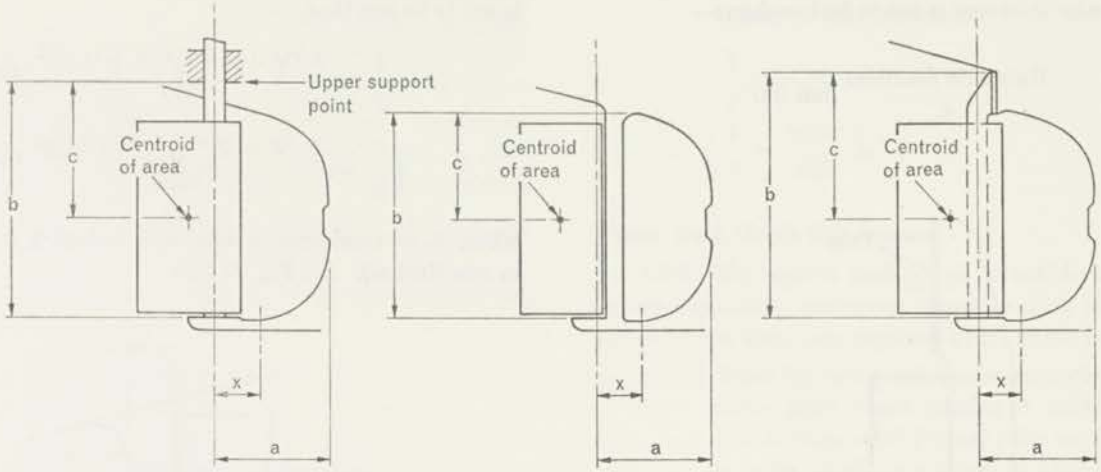
$w = 120\sqrt{d}$ mm ($w = 2{\cdot}60\sqrt{d}$ in)
$t_1 = 12\sqrt{d}$ mm ($t_1 = 0{\cdot}26\sqrt{d}$ in)
$t_2 = 15\sqrt{d}$ mm ($t_2 = 0{\cdot}325\sqrt{d}$ in)
$t_3 = 18\sqrt{d}$ mm ($t_3 = 0{\cdot}390\sqrt{d}$ in)
$r = 20\sqrt{d}$ mm ($r = 0{\cdot}433\sqrt{d}$ in)

Solepiece

1212 (i) The minimum section modulus of a cast steel solepiece against transverse bending $\frac{I}{y_t}$, at any point in the solepiece at a distance x metres (feet) from the centreline of the rudder pintles or their equivalent, is not to be less than:—

$$\frac{I}{y_t} = \frac{400Ac\,(V+3)^2\,(3x+a)}{b\,(L+640)}\ \text{cm}^3$$

$$\left(\frac{I}{y_t} = \frac{2{\cdot}27Ac\,(V+3)^2\,(3x+a)}{b\,(L+2100)}\ \text{in}^3\right)$$



(a) Open stern frame (b) Integral rudder post (c) Bolted axle

FIG. D 12.4

where a, b, c and x, in metres (feet), are as shown in Figs. D 12.4 (a), D 12.4 (b) and D 12.4 (c) and A = total area of rudder in m^2 (ft^2).

(ii) For a fabricated solepiece the minimum transverse section modulus may be taken as $0{,}85 \frac{I}{y_t}$.

(iii) Where the solepiece is connected to the upper part of the sternframe by a bolted axle, the section modulus in (i) or (ii) above may be reduced by 5 per cent. Where an integral rudder post is fitted having scantlings in accordance with 1216, the section modulus in (i) or (ii) above may be reduced by 50 per cent.

1213 The minimum section modulus against vertical bending is not to be less than $0{,}50 \frac{I}{y_t}$ if the sternframe is open, not less than $0{,}40 \frac{I}{y_t}$ if a bolted rudder post is fitted and not less than $0{,}35 \frac{I}{y_t}$ if an integral rudder post is fitted.

1214 In fabricated solepieces, transverse webs are to be fitted not more than 760 mm (30 in) apart; they need not be attached to the top plate.

A centreline vertical web is to be fitted where the breadth of the solepiece exceeds 900 mm (35·4 in).

Propeller Boss

1215 The finished thickness of the propeller boss is not to be less than $0{,}1d_s + 56$ mm $(0{\cdot}1d_s + 2{\cdot}2$ in), where d_s is the shaft diameter, in mm (inches).

Rudder Post

1216 Rudder posts supported at their lower end by a solepiece are to have a section modulus against transverse bending not less than:—

$$\frac{I}{y} = \frac{Ab\,(V+3)^2}{6{,}8}\ \text{cm}^3 \quad \left(\frac{I}{y} = \frac{Ab\,(V+3)^2}{3930}\ \text{in}^3\right)$$

where A and b are as defined in 1212.

Rudder Axle

1217 The design of the axle is to be such as to avoid sudden changes of section.

The diameter of an axle for a balanced type rudder is not to be less than $25d + 76$ mm ($0{\cdot}3d + 3$ in) but need not exceed 90 per cent of D_2. The diameters D_1 and D_2 are not to be less than required by D 2208 for rudder pintles and the lengths l_1 and l_2 are not to be less than $1{,}2\ D_1$ and $1{,}2\ D_2$ respectively (*see* Fig. D 12.5). The bearing pressure is to be in accordance with D 2209.

1218 The axle is to be connected to the hull by 6 bolts in a palm flange as shown in Fig. D 12.5. The diameter of the bolts and palm thickness is not to be less than:—

$$\frac{\text{Rule axle diameter}}{4} \text{ mm (in)}$$

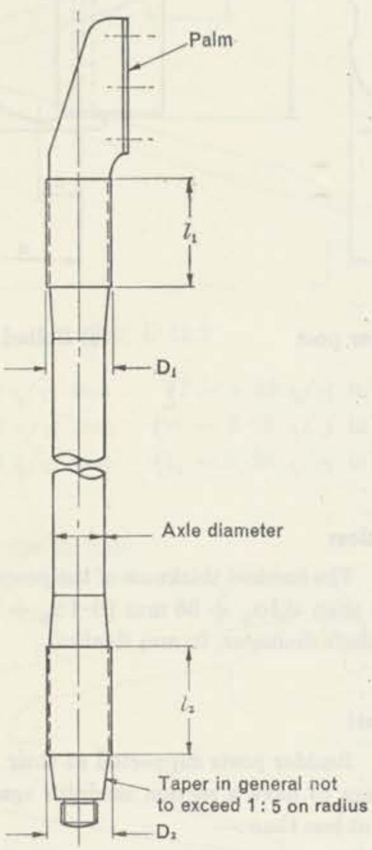


FIG. D 12.5

The mean distance of the bolt centres from the centre of the palm face is not to be less than the Rule axle diameter in 1217. If more than 6 bolts are fitted, the arrangements are to provide equivalent strength.

Rudder Horn

1219 Rudder horns may be cast or fabricated; if fabricated, Grade D steel is to be used for plates exceeding 25,5 mm (1 in) in thickness. They are to be efficiently integrated into the main hull structure and the radius at the shell connection is not to be less than 305 mm (12 in).

1220 The section modulus against transverse bending of a rudder horn when supporting a semi-spade type rudder is not to be less than:—

$$\frac{I}{y} = \frac{A\,(V+3)^2\sqrt{h^2+0{,}5g^2}}{530}\ \text{cm}^3$$

$$\left(\frac{I}{y} = \frac{A\,(V+3)^2\sqrt{h^2+0{\cdot}5g^2}}{3680}\ \text{in}^3\right)$$

where A = total area of rudder, in m^2 (ft^2), h and g are in mm (inches). *See* Fig. D 12.6.

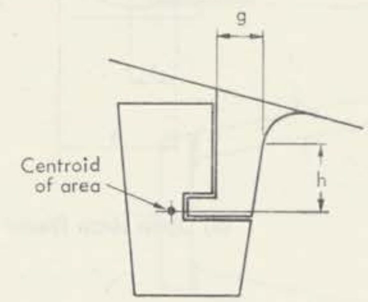


FIG. D 12.6

Propeller Clearances

1221 For recommended minimum propeller clearances for single and twin screw ships, *see* Chapter R (G).

Ice Strengthening

1222 For strengthening for navigation in ice, *see* D 24.

Section 13

DECK GIRDERS AND TRANSVERSES

Symbols

1301 S = span of girder or transverses, in metres (feet), between points of support. If an end bracket is fitted the span may be taken to a point which is half the distance between the toe of the end bracket and the support point.

b = mean width, in metres (feet), of deck (or deck and hatchway where applicable) supported by the girder or transverse.

h = load height, in metres (feet), as given in D 6 and D 8 (*See also* 1304, 1319 and D 25).

d_w = depth of web, in mm (inches).

General

1302 For the forward 0,075L of forecastle and weather decks, longitudinal girders supporting beams are not to be spaced more than 3,7 m (12·1 ft) apart, and transverses supporting deck longitudinals are not to be spaced more than 2,5 m (8·2 ft) apart. Elsewhere, transverses supporting deck longitudinals are to be spaced not more than 3,7 m (12·1 ft) apart when the length does not exceed 185 m (605 ft) and $\frac{L}{50}$ for lengths greater than 185 m (605 ft).

The web thickness of girders or transverses should not be less than:—

$$t = 9 + 0{,}008\left(\frac{d_w}{50}\right)^2 \text{ mm}$$

$$\left(t = 0{\cdot}35 + 0{\cdot}2\left(\frac{d_w}{50}\right)^2 \text{ in}\right)$$

Longitudinal Girders and Transverses supporting Deck Longitudinals

1303 The section modulus for longitudinal girders or transverses supporting deck longitudinals is not to be less than:—

$$\frac{I}{y} = 4{,}75 bhS^2 \text{ cm}^3$$

$$\left(\frac{I}{y} = \frac{bhS^2}{400} \text{ in}^3\right)$$

In single deck ships the section modulus of the transverses is to be increased by 15 per cent.

1304 On weather decks forward of 0,075L from the fore perpendicular, the section modulus of longitudinal girders and transverses supporting deck longitudinals is to be based on the above formula, using the h for weather deck amidships increased by 3 m (9·84 ft) and the depth of the girder or transverse is not to be less than twice that of the beam or longitudinal supported.

Weather Deck Hatch Side Girders (including Coamings)

1305 The section modulus for weather deck hatch side girders supporting transverse beams or deck transverses is not to be less than that required by (i) or (ii) below.

(i) When the hatch side girder supports one, two or three point loads (taking a stowage rate of 1,39 m^3/tonne (50 ft^3/ton)) the section modulus is to be based on a stress of 1025 kg/cm^2 (6·5 ton/in^2) assuming 100 per cent end fixity,

(ii) When the hatch side girder supports four or more point loads from deck transverses, or an evenly distributed load:—

$$\frac{I}{y} = 5{,}85 bhS^2 \text{ cm}^3$$

$$\left(\frac{I}{y} = \frac{bhS^2}{325} \text{ in}^3\right)$$

'Tween Deck Hatch Side Girders

1306 The section modulus of 'tween deck hatch side girders supporting transverse beams or deck transverses is not to be less than that required by (i) or (ii) below.

(i) When the hatch side girder supports one, two or three point loads (taking a stowage rate of 1,39 m^3/tonne (50 ft^3/ton)) the section modulus is to be based on a stress of 1150 kg/cm^2 (7·3 ton/in^2) assuming 100 per cent end fixity.

(ii) When the hatch side girder supports four or more point loads from deck transverses, or an evenly distributed load:—

$$\frac{I}{y} = 5{,}20 bhS^2 \text{ cm}^3$$

$$\left(\frac{I}{y} = \frac{bhS^2}{365} \text{ in}^3\right)$$

Hatch End Beams

1307 Where the deck is transversely framed, hatch end beams supported at the centreline and carrying hatch side coamings and longitudinal girders in line, are to have a section modulus not less than:—

$$\frac{I}{y} = 19K_1\, S\,(S_1\, b_1\, h + S_2\, b_2\, h) + z_1 \text{ cm}^3$$

$$\left(\frac{I}{y} = \frac{K_1\, S}{100}(S_1\, b_1\, h + S_2\, b_2\, h) + z_1 \text{ in}^3\right)$$

where S = span of hatch end beam, in metres (feet). *See* 1301,

S_1 = span of hatch side girder, in metres (feet),

b_1 = mean width, in metres (feet), of deck and hatchway supported by hatch side girder,

S_2 = span of the adjacent longitudinal girder in line, in metres (feet),

b_2 = mean width, in metres (feet), of deck supported by the adjacent longitudinal girder in line,

z_1 = an increase dependent upon the constructional arrangement between the hatch openings. *See* 1308,

b_h = breadth of hatchway, in metres (feet),

K_1 = a factor obtained from Table D 13.1.

TABLE D 13.1

$\frac{b_h}{2S}$	K_1
0,20	0,143
0,30	0,177
0,40	0,191
0,50	0,187
0,60	0,179
0,70	0,169
0,80	0,141
0,90	0,085
1,00	0

1308 If there is an additional longitudinal girder situated inboard of the line of hatch side girder and between the hatches then:—

$$z_1 = 19K_1\, S\,(S_4\, b_4\, h)\ \text{cm}^3$$

$$\left(z_1 = \frac{K_1\, S}{100}(S_4\, b_4\, h)\ \text{in}^3\right)$$

where

S_4 = span of the additional longitudinal girder, in metres (feet),

b_4 = mean width, in metres (feet), of deck supported by the additional longitudinal girder,

K_1 = a factor obtained from Table D 13.1 but taking b_h equal to twice the distance between the ship's centreline and the additional longitudinal girder.

1309 When the deck is framed longitudinally the hatch end beam is to have a section modulus not less than that required by (i) or (ii) below.

(i) When there are no transverses between the hatch end beam and the adjacent transverse bulkhead or equivalent support structure:—

$$\frac{I}{y} = 19K_1\, S\,(S_1\, b_1\, h) + 2{,}37 b_3\, h\, S^2\ \text{cm}^3$$

$$\left(\frac{I}{y} = \frac{K_1\, S}{100}(S_1\, b_1\, h) + \frac{b_3\, h\, S^2}{800}\ \text{in}^3\right)$$

where b_3 = distance, in metres (feet), between the hatch end beam and the adjacent transverse bulkhead or equivalent support structure.

K_1, S, S_1, and b_1 are as defined in 1307.

(ii) When there are one or more transverses between the hatch end beam and the adjacent transverse bulkhead or equivalent support structure:—

$$\frac{I}{y} = 19K_1\, S\,(S_1\, b_1\, h + S_3\, b_1\, h)\ \text{cm}^3$$

$$\left(\frac{I}{y} = \frac{K_1\, S}{100}(S_1\, b_1\, h + S_3\, b_1\, h)\ \text{in}^3\right)$$

where

S_3 = distance, in metres (feet), between the hatch end beam and the adjacent transverse bulkhead or equivalent support structure,

K_1, S, S_1, and b_1 are as defined in 1307.

Inertia

1310 The moment of inertia of deck girders is not to be less than:—

$$I = K_2 \frac{I}{y} S\ \text{cm}^4\ (\text{in}^4)$$

where K_2=2,3 (0·275 British) for weather deck hatch side girders

1,85 (0·222 British) for other longitudinal girders,

2,8 (0·336 British) for hatch end beams,

$\frac{I}{y}$ = Rule section modulus of the girder, in cm³ (in³).

End Connections

1311 Girders, deck transverses and hatch end beams are to have stiffened end brackets (with a suitable face flat) having the same thickness as the girder web plate. The distance from the deck to the toe of the bracket is not to be less than:—

$$150 + 52\sqrt[3]{\frac{I}{y}}\ \text{mm}$$

$$\left(6 + 5{\cdot}2\sqrt[3]{\frac{I}{y}}\ \text{in}\right)$$

where $\frac{I}{y}$ is the Rule section modulus of the girder, in cm³ (in³).

The horizontal arm of the bracket is not to be less than the depth of the bracket below the girder.

For welding requirements, *see* Table D 32.1.

Effective Flange

1312 The effective area of the attached deck plating to be included in the section modulus calculation for symmetrical and unsymmetrical girders (including weather deck hatch coamings) and box girders, is to be calculated as given in D 5304.

For minimum thickness of deck plating in association with girders, *see* D 414.

Details

1313 Girders of unsymmetrical section are to be supported by tripping brackets at alternate beams or equivalent; if the section is symmetrical the brackets may be four frame spaces apart. Where the ratio of the unsupported width of the girder face flat or flange to its thickness is

16 or greater, the tripping brackets are to be connected to the face flat or flange. On girders of symmetrical section tripping brackets are to be fitted on both sides when they are required to be connected to the flange. Intermediate beams are to be connected to the girder by welding or by lugs.

If the girder is not continuous between bulkheads, the part which is under the deck is to be extended beyond the end point of support for at least two frame spaces before commencing tapering off the web depth.

1314 Continuity is to be efficiently maintained over the heads of pillars, and tripping brackets fitted in way.

1315 At the corners of all hatchways supported by hatch end beams, horizontal gusset plates are to be fitted connecting the side girders to the hatch end beams. The gusset plates should taper off in the fore and aft direction over not less than one frame space; the taper outboard is to be over a similar distance and inboard not less than 450 mm (17·7 in). The thickness is to be not less than the maximum thickness of the face flats being connected.

1316 Weather deck deep hatch coamings acting as girders should be extended beyond the hatchway ends in the form of brackets, the coamings below the deck are to be effectively connected to the hatch end beams.

Where extension above the deck is not practicable the coaming below the deck is to be extended at least two frame spaces beyond the hatch end beams.

Additional Loads

1317 Where a girder is subject to concentrated loads, such as pillars out of line, the scantlings are to be suitably increased.

Where concentrations of loading on one side of the girder may occur, the girder should be adequately stiffened against torsion.

Additional attachments may be required to meet particular local stresses.

1318 Where cargoes such as chilled meat are suspended from a deck which may be simultaneously loaded above, the scantlings of the girders are to be increased in accordance with D 603, D 605, D 807 and D 810.

Timber Deck Cargoes

1319 Where timber load lines are to be assigned, h in the foregoing sections for weather decks is to be taken as 1,5 m (5 ft) where the beam B does not exceed 15 m (49 ft), and 1,83 m (6 ft) where the beam is 18 m (59 ft) or over, with intermediate values in proportion. In single deck ships the section modulus of the transverses supporting deck longitudinals is to be increased by 40 per cent.

Grades of Steel

1320 For special steel requirements in girder webs on refrigerated ships, *see* D 422.

Cross-References

1321 For cantilevers, *see* D 15.

Section 14

PILLARS AND NON-WATERTIGHT PILLAR BULKHEADS

Symbols

1401 P = load, in tonnes (tons), supported by the pillar and is to be equal to $\frac{Sb_d h}{\rho} + P_a$ but not less than 2 tonnes (1·97 tons).

S = distance, in metres (feet), between the centres of the two adjacent spans of girder supported by the pillar.

b_d = mean width of deck, in metres (feet), including hatchway if necessary, supported by the girders.

h = head, in metres (feet), supported by pillar, obtained from D 806, D 809 and D 1304.

P_a = load, in tonnes (tons), from pillar or pillars above (zero if no pillar above).

ρ = stowage rate and is to be taken as 1,39 m³/tonne (50 ft³/ton) unless specified otherwise.

A = cross-sectional area of pillar, in cm² (in²).

l = overall span of pillar, in metres (feet).

l_e = effective span of pillar, in metres (feet), where $l_e = 0{,}65l$ for hold pillars and $l_e = 0{,}8l$ for 'tween deck pillars.

r = minimum radius of gyration of pillar cross-section, in mm (inches).

d_p = mean diameter of tubular pillar, in mm (inches).

PILLARS

1402 The sectional area of pillars is not to be less than:—

$$A = \frac{P}{1{,}26 - 5{,}25\frac{l_e}{r}} \text{ cm}^2 \qquad (1)$$

$$\left(A = \frac{P}{8 - 0{\cdot}4\frac{l_e}{r}} \text{ in}^2\right)$$

As a first approximation A may be taken as $\frac{P}{0{,}95}$ $\left(\frac{P}{6}\text{ British}\right)$ and the radius of gyration estimated for a suitable section having this area. If the area calculated using this radius of gyration differs by more than 10 per cent from the first approximation, a further calculation using the radius of gyration corresponding to the mean area of the first and second approximations is to be made.

For tubular pillars the wall thickness is not to be less than:—

$$t = \frac{P}{0{,}04\, d_p - 0{,}5\, l_e} \text{ mm, or } \frac{d_p}{40} \text{ mm} \qquad (2)$$

$$\left(t = \frac{P}{25 \cdot 4\, d_p - 3 \cdot 8\, l_e} \text{ in, or } \frac{d_p}{40} \text{ in}\right)$$

whichever is the greater.

1403 Where pillars support eccentric loads they are to be strengthened for the additional bending moment imposed upon them.

1404 For the sides of hollow square pillars or web plates of Channel or I sections the ratio of the breadth to the thickness is not to exceed:—

$$600 \frac{l_e}{r} \quad \left(7 \cdot 2 \frac{l_e}{r} \text{ British}\right) \text{ or } 55$$

whichever is the greater.

The thickness of tubular and hollow square pillars is to be not less than 7,5 mm (0·30 in).

For ordinary angle or channel sections the ratio of the breadth to the thickness of the flanges is not to exceed:—

$$200 \frac{l_e}{r} \quad \left(2 \cdot 4 \frac{l_e}{r} \text{ British}\right) \text{ or } 18$$

whichever is the greater.

For fabricated sections or the flanges of I section pillars the ratio of the breadth to the thickness of face plates is not to exceed:—

$$400 \frac{l_e}{r} \quad \left(4 \cdot 8 \frac{l_e}{r} \text{ British}\right) \text{ or } 36$$

whichever is the greater.

General

1405 Pillars are to be fitted in the same vertical line wherever possible and effective arrangements are to be made to distribute the load at the heads and heels of all pillars.

1406 Tubular and hollow square pillars are to be attached at their heads to plates supported by brackets, flanged where necessary, in order to transmit the load effectively. Doubling or insert plates are to be fitted to the inner bottom under the heels of tubular or hollow square pillars, and to decks under large pillars.

The pillars are to have a bearing fit and are to be attached to the head and heel plates by continuous welding.

1407 At the heads and heels of pillars built of rolled sections the load is to be well distributed by means of longitudinal and transverse brackets.

1408 In double bottoms under widely spaced pillars the connections of the floors to the girders and of the floors and girders to the inner bottom are to be suitably increased. Where pillars are not directly above the intersection of plate floors and girders, partial floors and intercostals are to be fitted as necessary to support the pillars. Manholes are not to be cut in the floors and girders below the heels of pillars.

Where longitudinal framing is adopted in the double bottom, equivalent stiffening under the heels of pillars is to be provided.

1409 Where the heels of pillars are carried on a tunnel, suitable arrangements are to be made to support the load.

1410 Where pillars are fitted inside tanks or under watertight flats the tensile stress in the pillar and its end connections is not to exceed 1100 kg/cm² (7 ton/in²). In general, such pillars should be of built sections.

1411 Pillars are to be fitted below deck-houses, windlasses, winches, capstans and elsewhere where considered necessary. The structure in way of the boat davits is to be strengthened.

1412 Arrangements for supporting the structure in machinery spaces will be considered.

For pillars under forecastles in tankers, *see* D 5437.

Timber Deck Cargoes

1413 Where timber load lines are to be assigned the head to be used when calculating weather deck pillars is to be in accordance with D 1319.

NON-WATERTIGHT PILLAR BULKHEADS

1414 The thickness of bulkhead plating is not to be less than 7,5 mm (0·30 in) in holds and 6,5 mm (0·26 in) in 'tween decks.

1415 Stiffeners are to be spaced not more than 1500 mm (59·1 in) apart.

1416 Stiffeners or corrugations are not to be less in depth than 150 mm (6 in) in holds and 100 mm (4 in) in 'tween decks.

1417 Rolled, built, swedged or corrugated stiffeners supporting deck beams, longitudinals, girders or transverses, are to have a sectional area (including attached plating) not less than that given below for the two cases:—

(i) where

$$\frac{s}{t} \text{ exceeds } 500\frac{l_e}{r} \quad \left(6{\cdot}0\frac{l_e}{r} \text{ British}\right)$$

for rolled or built sections and swedges

or (ii) where $\frac{b}{t}$ exceeds

$$\frac{750\lambda}{(\lambda + 0{,}25)}\frac{l_e}{r} \quad \left(\frac{9\lambda}{(\lambda + 0{\cdot}25)}\frac{l_e}{r} \text{ British}\right)$$

for symmetrical corrugations

$$\text{then } A = \frac{P}{0{,}5 - 1{,}5\frac{l_e}{r}} \text{ cm}^2$$

$$\left(A = \frac{P}{3{\cdot}18 - 0{\cdot}114\frac{l_e}{r}} \text{ in}^2\right)$$

where s = stiffener spacing, in mm (in), for rolled or built sections, or breadth of flat plating for swedges,

b, c, d and t are as shown in Fig. D 14.1 for symmetrical corrugations, measured in mm (in),

$$\lambda = \frac{b}{c}$$

$$r = 10\sqrt{\frac{I}{A}} \text{ mm} \quad \left(r = \sqrt{\frac{I}{A}} \text{ in}\right)$$

for rolled or built sections and swedges

where I = inertia in cm^4 (in^4) of stiffener with 610 mm (24 in) of attached plating,

A = area in cm^2 (in^2) of stiffener with attached plating of breadth s,

$$r = d\sqrt{\frac{3b + c}{12(b + c)}} \text{ for symmetrical corrugations.}$$

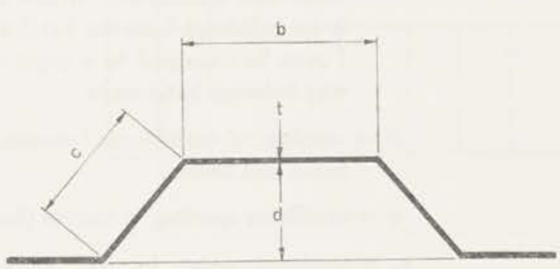


FIG. D 14.1

For a first approximation A may be taken as $\frac{P}{0{,}4}$ $\left(\frac{P}{2{\cdot}5}\text{British}\right)$.

Where $\frac{s}{t}$ and $\frac{b}{t}$ do not exceed the above limits the area of stiffener and total attached plating is to be in accordance with 1402.

1418 The connections of bulkheads to deck and inner bottom are to be in accordance with Table D 32.1.

Section 15

CANTILEVERS

1501 This section gives the required scantlings for cantilevers and their supporting frames. Section moduli for cantilevers not at hatch sides are given in 1503. Section moduli for hatch side cantilevers are given in 1504 and 1505. The remaining paragraphs in this section refer to all cantilevers.

Symbols

1502

$\left(\frac{I}{y}\right)_1, \left(\frac{I}{y}\right)_2, \left(\frac{I}{y}\right)_3$ = mean of section moduli, in cm^3 (in^3), of hatch end beams calculated for the positions shown in Fig. D 15.2.

$\left(\frac{I}{y}\right)_{s_1}$ = section modulus, in cm^3 (in^3), of hatch side girder.

$\left(\frac{I}{y}\right)_{s_2}$ = mean of section moduli, in cm^3 (in^3), of longitudinal girders in line with hatch side girder. $\left(\frac{I}{y}\right)_{s_2}$ is not to be taken greater than $\left(\frac{I}{y}\right)_{s_1}$.

$\left(\frac{I}{y}\right)_u$ = section modulus, in cm^3 (in^3), of frame or stiffener above cantilever. When there are no frames or stiffeners above cantilevers, $\left(\frac{I}{y}\right)_u = 0$.

$$\beta = \frac{c}{l}$$

ρ = stowage rate, and is to be taken as 1,39 m^3/tonne (50 ft^3/ton) unless specified otherwise.

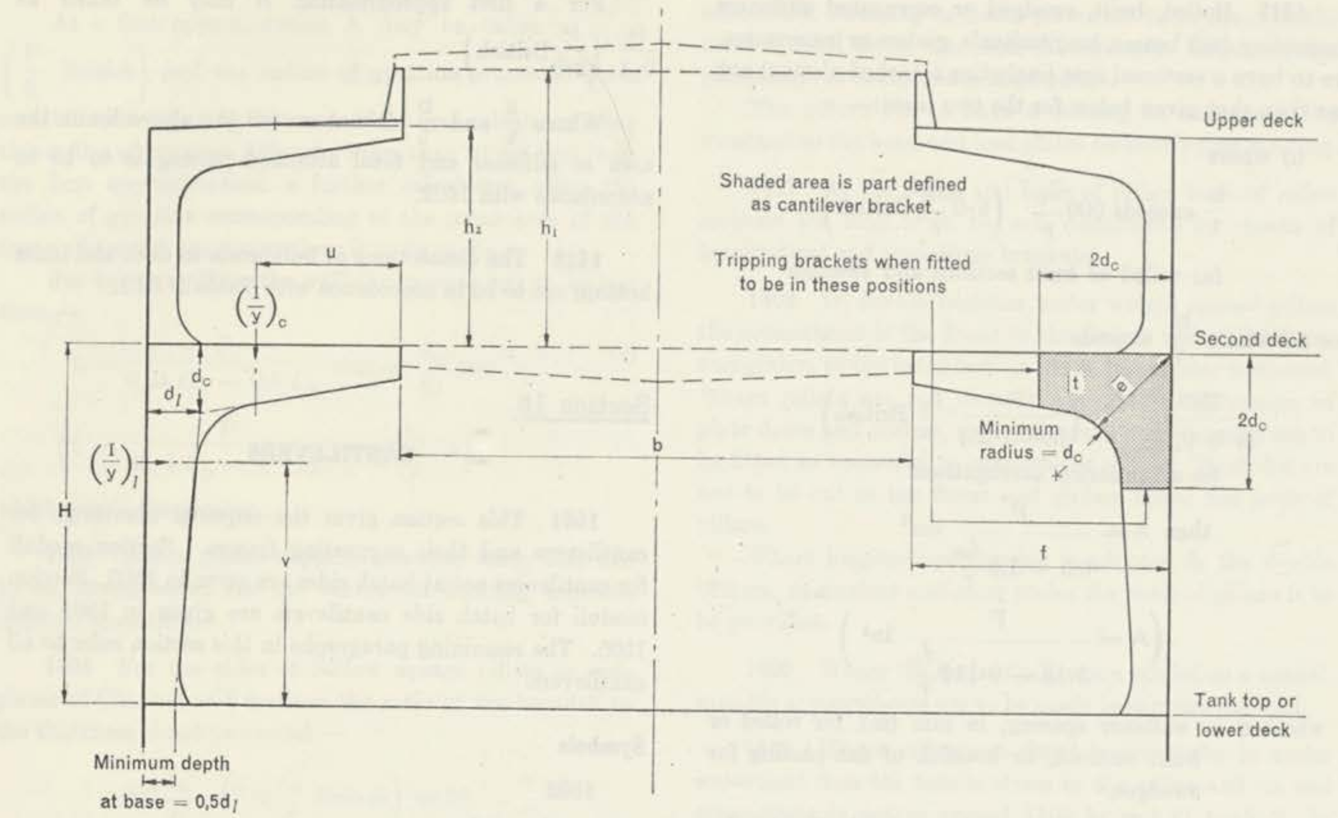


FIG. D 15.1

$$E = \frac{4}{n+1}\left[\left\{\left(\frac{I}{y}\right)_1 + \left(\frac{I}{y}\right)_2\right\} + \frac{2u}{b}\left\{\left(\frac{I}{y}\right)_2 + \left(\frac{I}{y}\right)_3\right\}\right]$$

where centreline bulkheads or centreline pillars are fitted.

$$E = \frac{4}{n+1}\left[\left(\frac{I}{y}\right)_1 + \left(\frac{I}{y}\right)_2\right]$$ where there is no support at the centreline.

$$G = \frac{7u}{(n+1)\,c}\left[\left(\frac{I}{y}\right)_{s_1} + \left(\frac{I}{y}\right)_{s_2}\right]$$

$$G_1 = \frac{3{,}5\,u}{s}\left(\frac{I}{y}\right)_{s_1}$$

M = bending moment in tonnes metres (tons ft) due to the load supported by a single cantilever. This bending moment is to be calculated about an axis distant u from hatch side, and for hatch side cantilevers with uniformly distributed loading it will be

$$\frac{su}{2\rho}\,(h_1\,b + h_2\,u).$$

c = distance, in metres (feet), between hatch end beams.

$$Z = \frac{f}{u}\left(\frac{I}{y}\right)_c$$

h_1 = mean height, in metres (feet), of cargo space above hatchway. (At weather decks, *see* D 806).

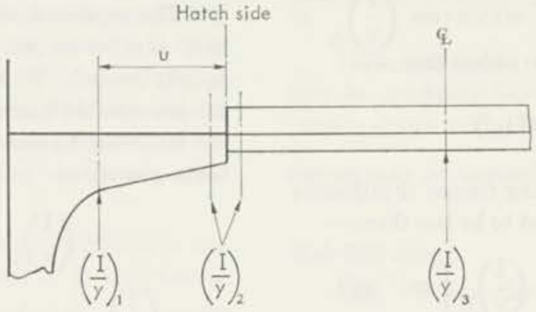
h_2 = mean 'tween deck height, in metres (feet), clear of hatchway. (At weather decks, *see* D 806).

l = distance, in metres (feet), between transverse bulkheads. Where there is no bulkhead between hatchways, l is to be measured to a point midway between hatchways.

n = number of cantilevers between the hatch end beams.

s = cantilever spacing, in metres (feet).

A_f = sectional area, in cm² (in²), of cantilever bracket face plate.



$\left(\frac{I}{y}\right)_2$ is the smaller modulus of the sections adjacent to the hatch side

Fig. D 15.2

d = web depth of cantilever or frame, in mm (in).

d_c = root depth, in mm (in), of cantilever, as indicated in Fig. D 15.1.

b, f, u, v and H are measured in metres (feet), as shown in Figs. D 15.1 and D 15.3.

t, d_l and e are measured in mm (in), as shown in Fig. D 15.1.

Note: The dimensions shown in Fig. D 15.1 are for calculating the second deck cantilevers. When other decks are being considered the deck indicated as "2nd Deck" is to be considered as the deck in question.

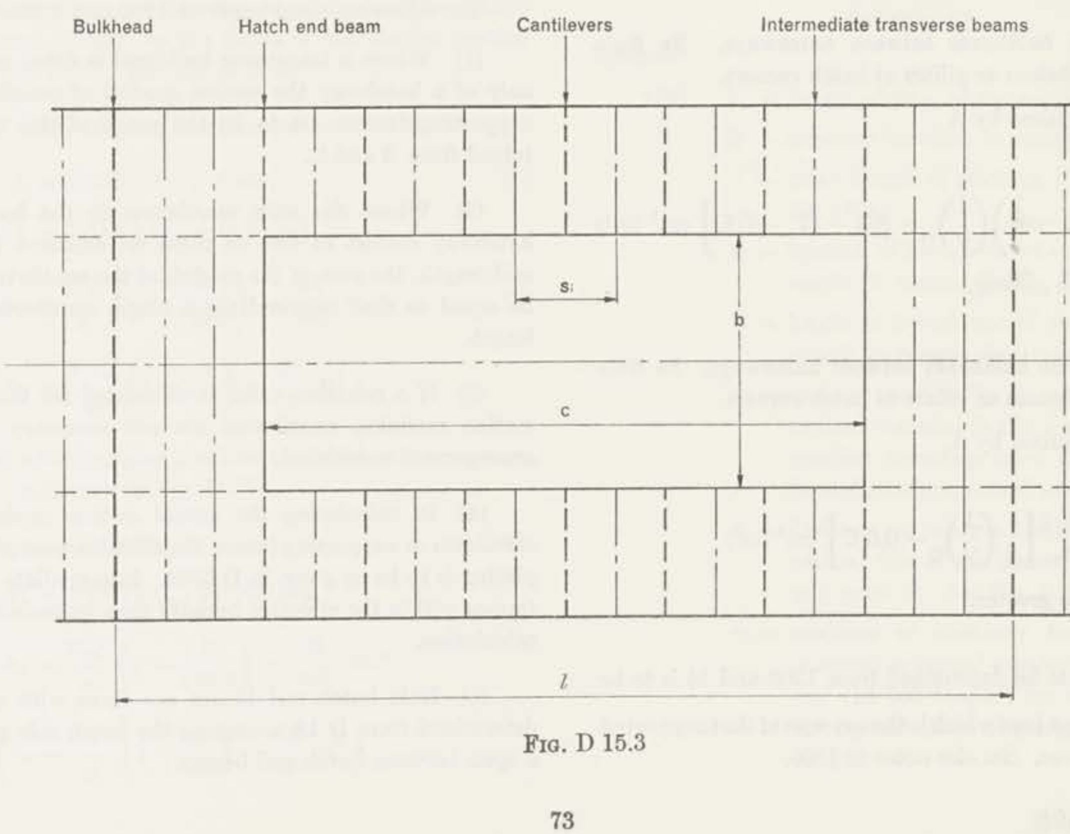


Fig. D 15.3

Cantilevers not at Hatch Sides

1503 The section modulus of cantilevers $\left(\frac{I}{y}\right)_o$ at distance u from the outer end is not to be less than:—

$$\left(\frac{I}{y}\right)_o = 85M \text{ cm}^3 \ (1{\cdot}6M \text{ in}^3)$$

The section modulus of supporting frames or stiffeners at distance v from the lower end is not to be less than:—

$$\left(\frac{I}{y}\right)_l = \frac{v}{H}\left[\frac{f}{u}\left(\frac{I}{y}\right)_o - \left(\frac{I}{y}\right)_u\right] \text{cm}^3 \ (\text{in}^3)$$

Hatch Side Cantilevers

1504

(i) **Uniform Loading**

The section modulus of cantilevers, $\left(\frac{I}{y}\right)_c$, at distance u from the hatch side is not to be less than:—

A **Hatch corners supported by Rule hatch end beams or pillars at hatch corners** (*see* 1505, Note (5)).

$$\left(\frac{I}{y}\right)_c = 0{,}9\left(\frac{I}{y}\right)_o - G \text{ cm}^3 \ (\text{in}^3)$$

B **Transverse bulkheads between hatchways. No Rule hatch end beams or pillars at hatch corners.**

As required by A

or

$$\frac{n+1}{n}\left[0{,}45\left(1+\frac{1}{\beta}\right)\left(\frac{I}{y}\right)_o - \beta G - (1-\beta)E\right] \text{cm}^3 \ (\text{in}^3)$$

whichever is the greater.

C **No transverse bulkheads between hatchways. No Rule hatch end beams or pillars at hatch corners.**

As required by A

or

$$\frac{n+1}{n}\left[\frac{1}{\beta}\left(\frac{I}{y}\right)_o - 0{,}5\,E\right] \text{cm}^3 \ (\text{in}^3)$$

whichever is the greater.

$\left(\frac{I}{y}\right)_o$ is to be determined from 1503 and M is to be calculated using a load which is the average of that supported by each cantilever. *See also* notes to 1505.

(ii) **Concentrated Loading**

The requirements in 1504(i) are based on the assumption that cantilevers are approximately equally spaced and equally loaded. Where a particular cantilever is subjected to concentrated loading, its modulus is to be that given by the following formula or as required by 1504(i) whichever is the greater:—

$$\left(\frac{I}{y}\right)_c = \left(\frac{I}{y}\right)_o - G_1 \text{ cm}^3 \ (\text{in}^3)$$

where $\left(\frac{I}{y}\right)_o$ is to be determined from 1503, and M is to be calculated using the particular load on the cantilever being considered.

Frames supporting Hatch Side cantilevers

1505 The section modulus, at a distance v above the tank top or lower deck, of frames supporting cantilevers is not to be less than:—

$$\left(\frac{I}{y}\right)_l = \frac{v}{H}\left[\frac{f}{u}\left(\frac{I}{y}\right)_c - \left(\frac{I}{y}\right)_u\right] \text{cm}^3 \ (\text{in}^3)$$

where $\left(\frac{I}{y}\right)_c$ is to be determined from 1504.

Notes

The following notes apply to 1504 and 1505:—

(1) Where a transverse bulkhead is fitted at one end only of a hatchway the section moduli of cantilevers and supporting frames are to be the mean of the values obtained from B and C.

(2) Where the only cantilevers in the length of a hatchway consist of two or three on adjacent frames at mid-length, the sum of the moduli of the cantilevers should be equal to that required for a single cantilever at mid-length.

(3) If a negative value is calculated for the required section modulus, cantilevers are not necessary with the arrangement considered.

(4) In calculating the actual section modulus of a cantilever or supporting frame, the effective area of attached plating is to be as given in D 5304. Intermediate beams or frames within the effective breadth may be included in the calculation.

(5) Rule hatch end beams are those with scantlings determined from D 13, assuming the hatch side girder has a span between hatch end beams.

GENERAL

1506 The section modulus of side frames supporting cantilevers is not to be less than that required by D 7 for side frames in the same position. The section modulus of cantilever beams is not to be less than that required by D 8 for beams in the same position. The scantlings of pillars or pillar bulkhead stiffeners supporting cantilevers must also comply with D 14.

The modulus of hatch side coamings or girders is not to be less than that required by D 1305 or D 1306 taking the span between the cantilevers.

Inertia

1507 The moment of inertia of cantilever beams at distance u from the hatch side or end of the cantilever is not to be less than:—

$$I = 9\,u\left(\frac{I}{y}\right)_c \text{ cm}^4 \quad \left(I = 1{\cdot}08\,u\left(\frac{I}{y}\right)_c \text{ in}^4\right).$$

$\left(\frac{I}{y}\right)_c$ is the Rule section modulus at the same position.

Cantilever Brackets

1508 The minimum thickness, t, of cantilever brackets and the minimum sectional area, A_f, of bracket face plates are to extend at least to the limits of the shaded portion shown in Fig. D 15.1 and are to be:—

(a) when tripping brackets are not fitted,

$$t = 0{,}0075\,d_c + 5 \text{ mm} \qquad (1)$$

$$\left(t = 0{\cdot}0075\,d_c + 0{\cdot}20 \text{ in}\right)$$

$$A_f = \frac{27Z}{e}\left(1 - \frac{e}{1420f}\right) - \frac{et}{300} \text{ cm}^2 \qquad (2)$$

$$\left(A_f = \frac{2{\cdot}7Z}{e}\left(1 - \frac{e}{17f}\right) - \frac{et}{3} \text{ in}^2\right)$$

(b) when tripping brackets are fitted at the positions indicated in Fig. D 15.1,

$$t = 0{,}0075\,d_c + 5 \text{ mm} \qquad (3)$$

$$\left(t = 0{\cdot}0075\,d_c + 0{\cdot}20 \text{ in}\right)$$

$$A_f = \frac{20Z}{e}\left(1 - \frac{e}{1420f}\right) - \frac{et}{200} \text{ cm}^2 \qquad (4)$$

$$\left(A_f = \frac{2Z}{e}\left(1 - \frac{e}{17f}\right) - \frac{et}{2} \text{ in}^2\right).$$

1509 In general, the radius at the throat of the cantilever is not to be less than d_c as indicated in Fig. D 15.1.

1510 Cantilever and supporting frame face plates may be gradually tapered from the limits of the shaded portion shown in Fig. D 15.1 and the web depth of supporting frames may be tapered to a minimum of $\frac{d_l}{2}$ at the base.

Web Stiffening

1511 Where the web thickness of cantilevers or supporting frames is less than $\frac{d}{60}$, transverse web stiffeners should be fitted spaced approximately 1,5d apart. Where stiffeners are fitted parallel to the face plates, the stiffening arrangements will be considered.

Minimum Web Thickness

1512 The web thickness of cantilevers and supporting frames outside the limits of the cantilever brackets, as shown in Fig. D 15.1, is not to be less than $\frac{d}{85}$.

Section 16

LONGITUDINAL STRENGTH IN WAY OF ERECTIONS

Symbols

1601 L = length of ship, in metres (feet).

B = moulded breadth, in metres (feet).

l = mean length of erection, in metres (feet). *See* 1604.

b = breadth of lowest tier of erections at mid-length, in metres (feet). *See* 1605.

h = height of lowest tier of erections at mid-length, in metres (feet), measured at side.

a = area, in cm^2 (in^2), of continuous longitudinal material in the lowest tier of the erection (openings need not, in general, be deducted) measured at amidships.

g = distance, in metres (feet), between the neutral axis of the lowest tier of erection and point R. *See* Fig. D 16.1.

e = modulus of elasticity for the erection material in kg/cm^2 (ton/in^2). ($2{,}1 \times 10^6$ kg/cm^2 (13 500 ton/in^2) for steel and $0{,}7 \times 10^6$ kg/cm^2 (4500 ton/in^2) for aluminium alloy).

E = modulus of elasticity for the hull material, in kg/cm² (ton/in²).

A = area of continuous longitudinal material in the main hull measured at amidships in cm² (in²).

G = distance, in metres (feet), between the neutral axis of the hull and point R. *See* Fig. D 16.1.

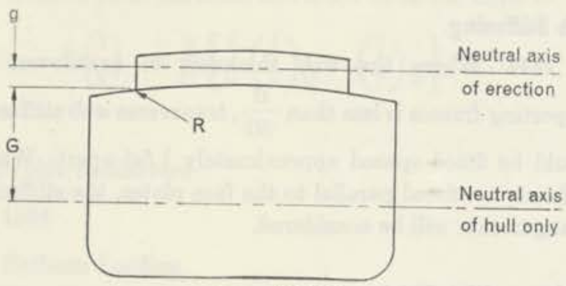


FIG. D 16.1

Where several tiers of erections are fitted, the calculation to determine their efficiency is to be carried out firstly for the lowest tier only and a correction applied later for the effect of tiers above. *See* 1607.

Application

1602 In this Section the term "erection" includes both superstructures and deckhouses.

1603 Where erections extending within 0,5L amidships and having lengths exceeding $42-\frac{30b}{B}$ m $\left(137{\cdot}8-\frac{98{\cdot}4b}{B}\text{ ft}\right)$ are fitted, the requirements of this Section are to be complied with in addition to those of D 17.

Tiers of Differing Length

1604 The length l of the erection to be used in the calculation is to be taken as the weighted mean value of those tiers whose length exceeds $0{,}7l_1$, as given below.

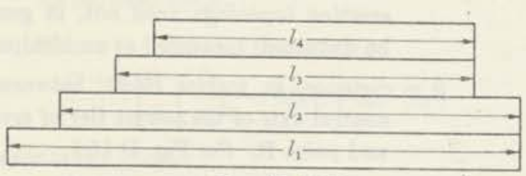


FIG. D 16.2

(i) when l_2, l_3 and $l_4 > 0{,}7l_1$,

$$l=\frac{8l_1+4l_2+2l_3+l_4}{15}$$

(ii) when $l_4 < 0{,}7l_1$ and l_2 and $l_3 > 0{,}7l_1$,

$$l=\frac{4l_1+2l_2+l_3}{7}$$

(iii) when l_4 and $l_3 < 0{,}7l_1$ and $l_2 > 0{,}7l_1$

$$l=\frac{2l_1+l_2}{3}$$

Any parts of the erection extending beyond the fore or aft perpendiculars are to be neglected.

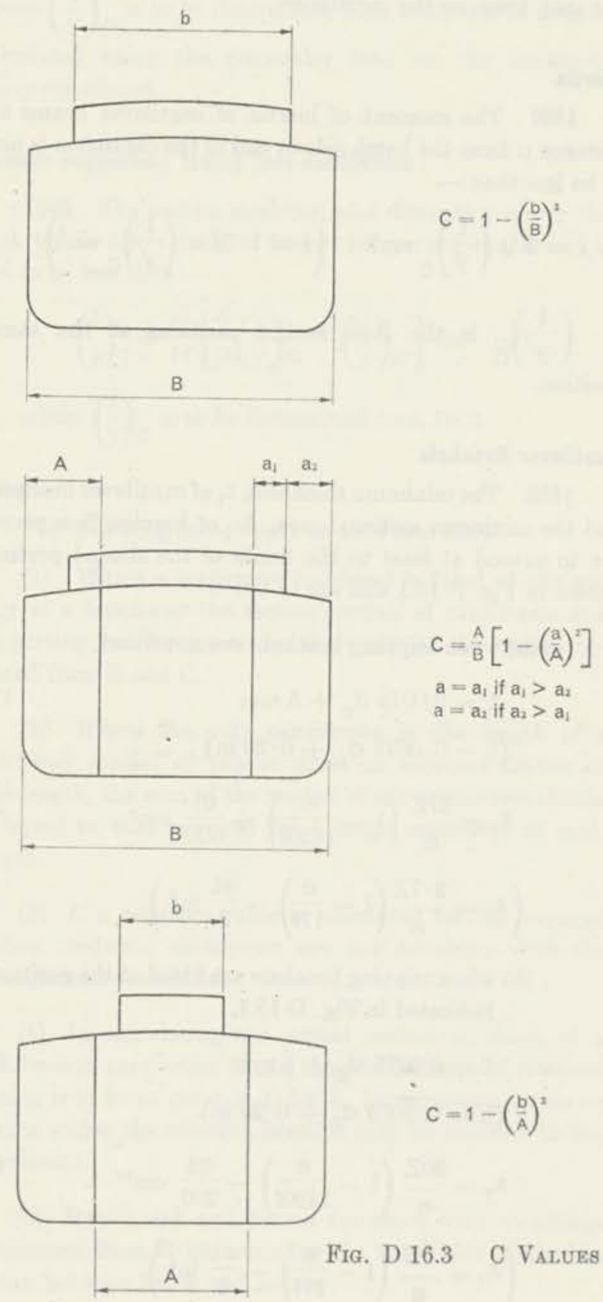


FIG. D 16.3 C VALUES

Tiers of Differing Breadth

1605 Upper tiers are not, in general, to be included in the calculation if their breadths are more than 3,7 m (12·1 ft) less than that of the lowest tier. If, however, upper tiers having less breadth are effectively supported by partial bulkheads or strong web frames below, spaced not more than 9,0 m (29·5 ft) apart, they may be included in the calculation. When the breadth of an upper tier is less than $\frac{b}{2}$ or $\frac{B}{3}$, whichever is smaller, its effect is negligible and it need not be included in the calculation.

Calculation Method

1606 The flexibility factor, ψ, for the deck upon which the lowest tier of the erection stands, is to be calculated from the following formula:—

$$\psi = 12\,KC^2 \frac{t}{h}\frac{e}{E} \qquad \left(\psi = 1000\,KC^2 \frac{t}{h}\frac{e}{E} \text{ British}\right)$$

where C = a constant depending upon the $\frac{b}{B}$ ratio or the number and location of longitudinal bulkheads fitted (if any) (*see* Fig. D 16.3),

K = a constant depending upon the number of transverse bulkheads in the hull under the erection, and is to be obtained from Table D 16.1 and notes,

t = thickness of the erection side plating in mm (inches).

NOTE: Continuous longitudinal bulkhead to be at least 6,0 m (19·7 ft) longer than the lowest tier of the erection.

1607 The basic erection efficiency factor η_1 is obtained from Fig. D 16.5 which is based upon the following standard ratios:—

$$\frac{b}{h} = 5{,}0$$

$$\frac{g}{G} = 0{,}35$$

$$\frac{ae}{AE} = 0{,}10$$

η_1 is then corrected for actual values of these ratios using Figs. D 16.6, D 16.7 and D 16.8, i.e. if $\frac{b}{h}$ differs from 5,0, Fig. D 16.6 is entered with the value of η_1 and a corrected value η_2 obtained. This value η_2 is then corrected using Fig. D 16.7 for variations in $\frac{g}{G}$ and η_3 obtained. Similarly η_4 is obtained from Fig. D 16.8.

A factor f is derived from Fig. D 16.9 and the final erection efficiency factor η_f is given by:—

$$\eta_f = \eta_4 f$$

For a single tier erection $f = 1$.

TABLE D 16.1—K VALUES

Number of transverse bulkheads in the hull under the erection.	One effective transverse bulkhead directly under the erection ends, or situated close to the ends and within the length of the deckhouse.	No effective transverse bulkhead under ends of erection.
0	—	300,0*
1	—	175,0
2	75,0	100,0
3	45,0	58,0
4	27,1	38,0
5	18,3	27,5
6	13,3	19,8
7	9,8	14,2
8	7,2	10,4
9	5,2	7,6
10	4,0	4,9

NOTES
1. *225 if deck transverses are fitted under the erection throughout.
2. If there is a transverse bulkhead under one end only, the mean value obtained from the 2nd and 3rd columns is to be used in the calculation.

1608 The following diagram is to be constructed:—

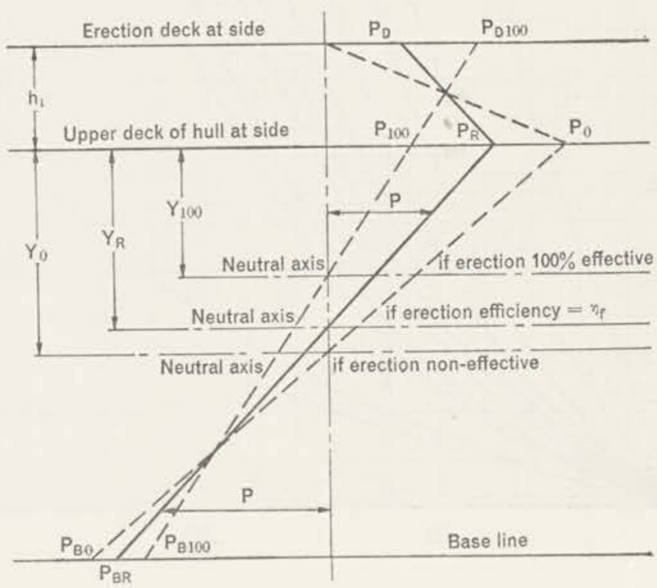


FIG. D 16.4

where $P_0 = \dfrac{100NY_0}{I_0}$ $\left(\dfrac{NY_0}{I_0}\text{ British}\right)$

$P_{100} = \dfrac{100NY_{100}}{I_{100}}$ $\left(\dfrac{NY_{100}}{I_{100}}\text{ British}\right)$

$P_R = P_0 - \eta_f\,(P_0 - P_{100})$

$P_{BR} = P_{B0} - \eta_f\,(P_{B0} - P_{B100})$

$P_{D100} = \dfrac{100N\,(Y_{100} + h_1)}{I_{100}}$ $\left(\dfrac{N\,(Y_{100} + h_1)}{I_{100}}\text{ British}\right)$

$P_D = \eta_f\,P_{D100}$

N = Rule $\dfrac{I}{y}$ for mild steel, in cm³ (in²ft), obtained from Section D 3,

I_0 = moment of inertia, in cm⁴ (in²ft²), of the hull only about the neutral axis,

I_{100} = moment of inertia, in cm⁴ (in²ft²), of hull and all tiers of effective erections about the neutral axis, assuming the erections to be 100 per cent effective.

Openings in erection sides and decks are to be deducted and the calculation carried out at the worst cross section including all effective erections within 0,2L fore and aft of amidships.

Where materials with modulus of elasticity e are used in the erections, the area of this material to be used in the calculation of I_{100} is the actual area multiplied by $\dfrac{e}{E}$,

Y_0, Y_R, and Y_{100} (*see* Fig. D 16.4) are to be measured in metres (feet).

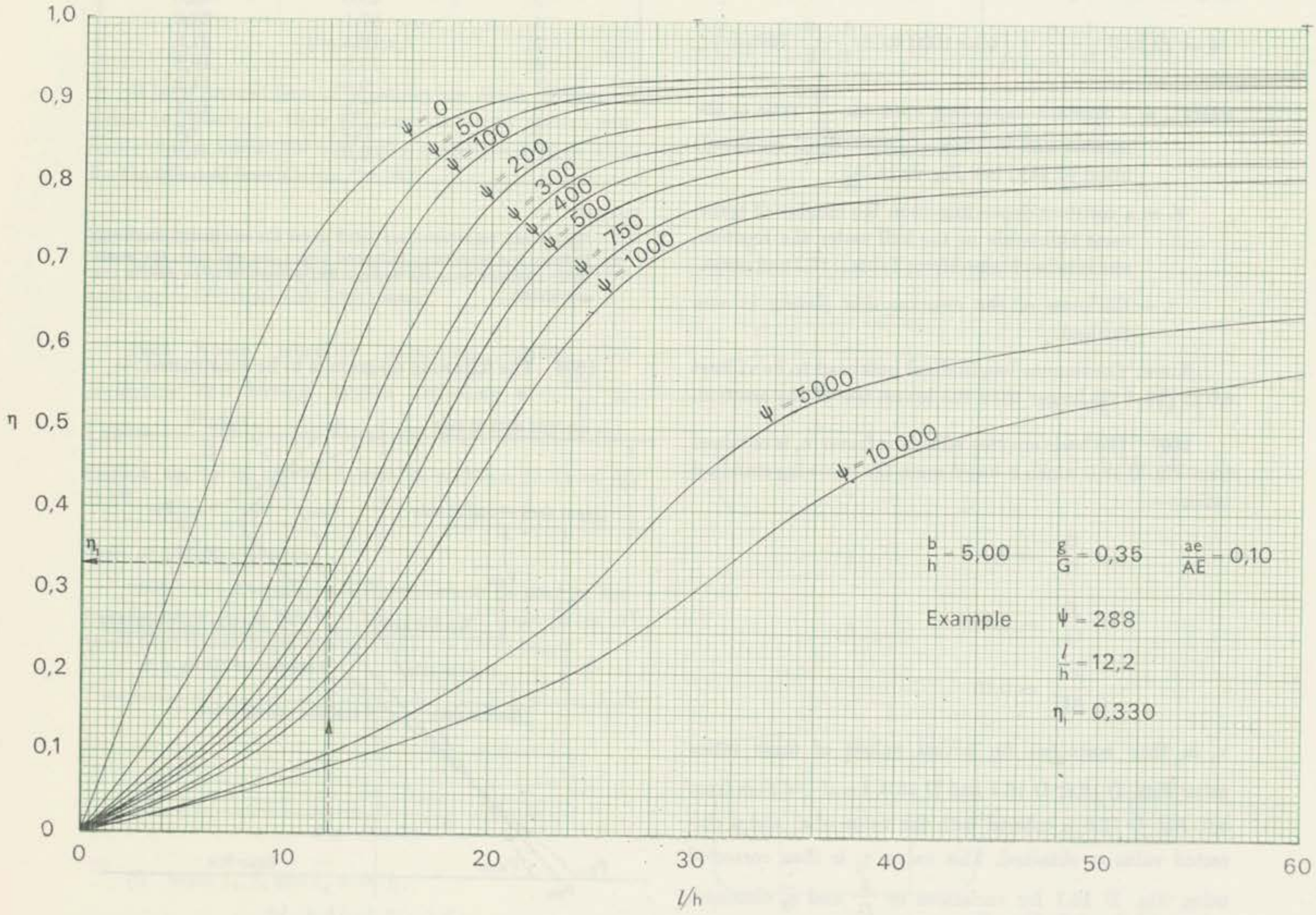


FIG. D 16.5

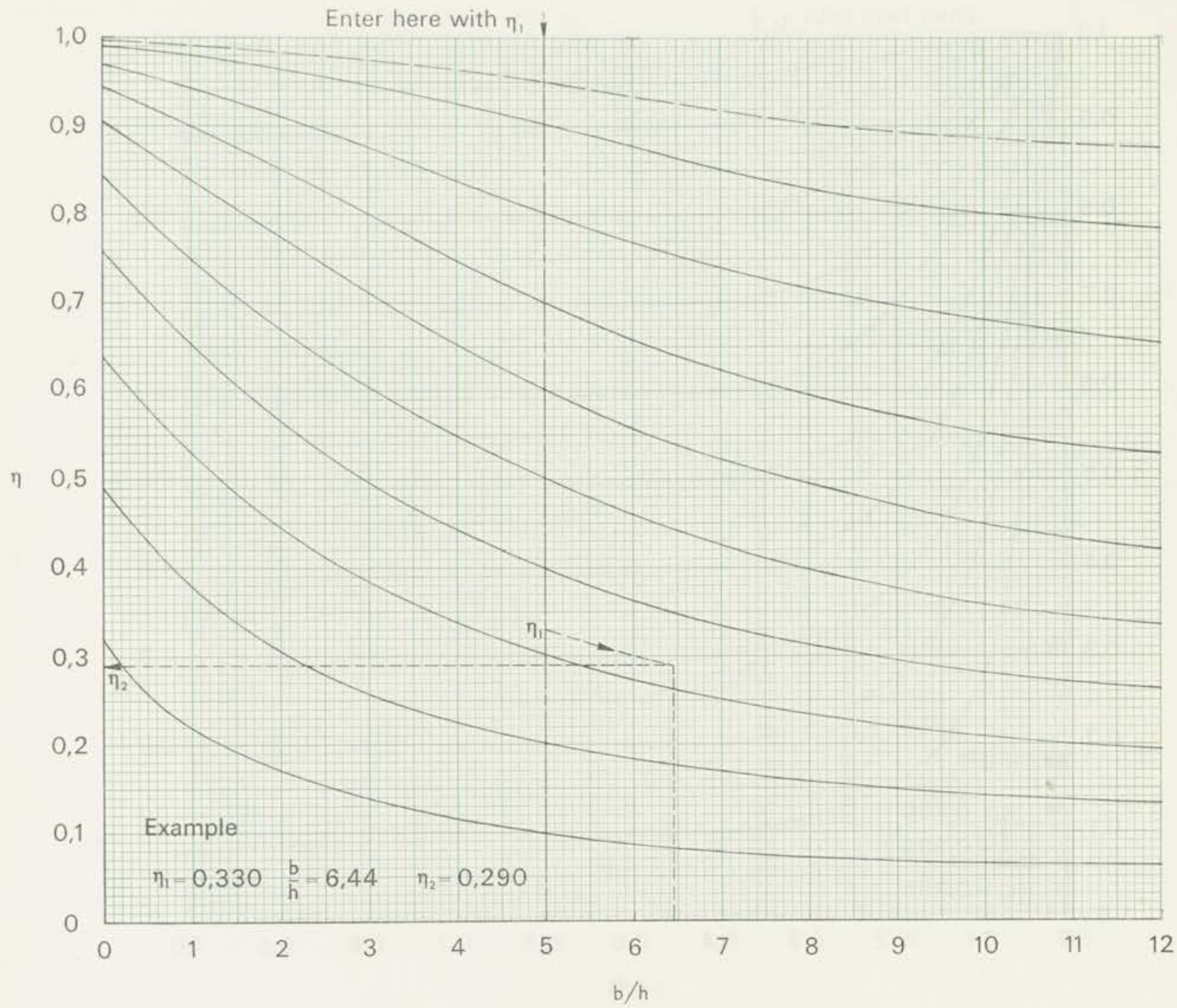
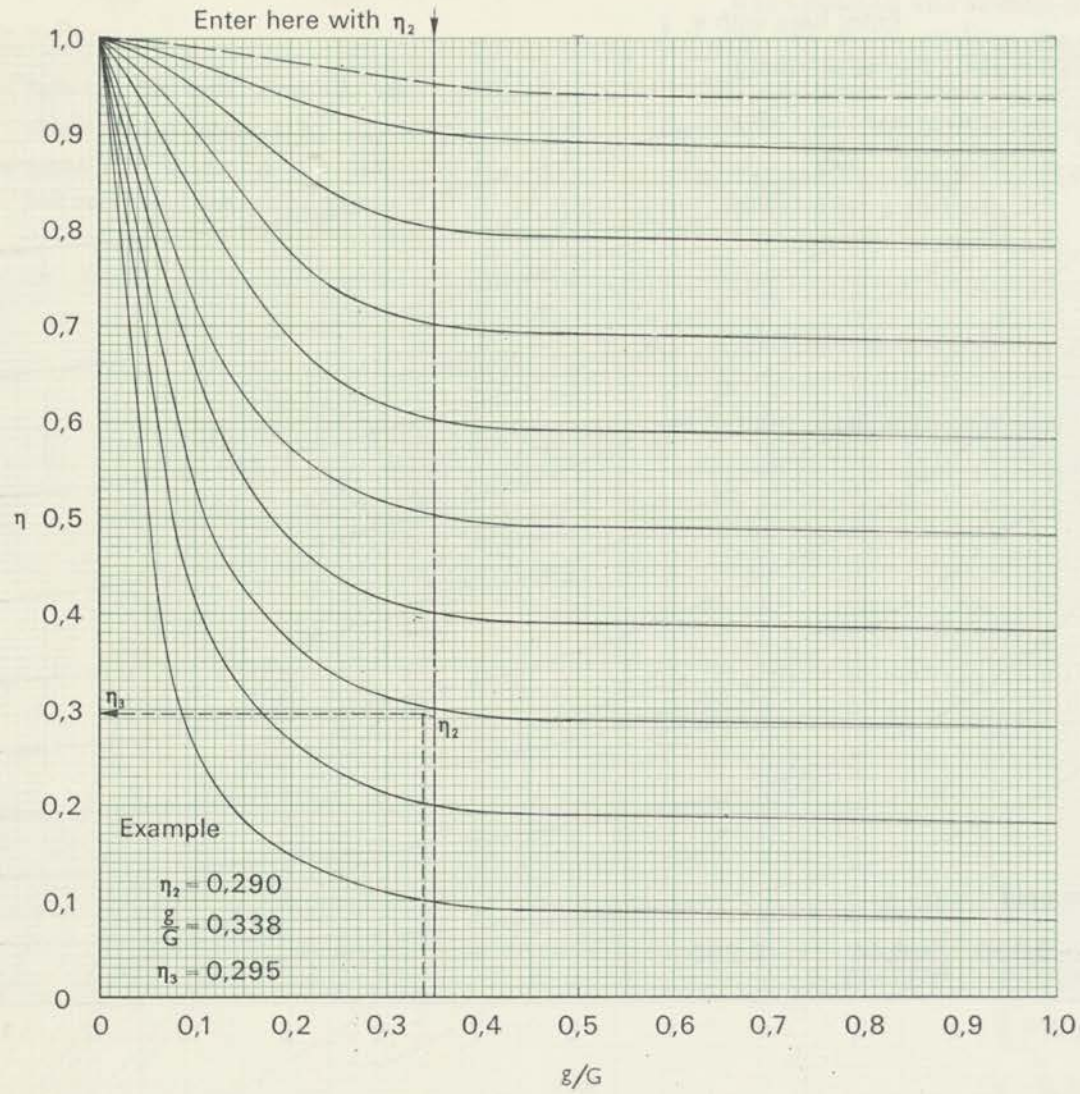

Enter here with η_1
1,0
0,9
0,8
0,7
0,6
η 0,5
0,4
0,3
0,2
0,1
0
η_1
η_2
Example
$\eta_1 = 0{,}330$ $\frac{b}{h} = 6{,}44$ $\eta_2 = 0{,}290$
0 1 2 3 4 5 6 7 8 9 10 11 12
b/h

Fig. D 16.6



Enter here with η_2
1,0
0,9
0,8
0,7
0,6
η 0,5
0,4
0,3
0,2
0,1
0
η_3
η_2
Example
$\eta_2 = 0,290$
$\frac{g}{G} = 0,338$
$\eta_3 = 0,295$
0 0,1 0,2 0,3 0,4 0,5 0,6 0,7 0,8 0,9 1,0
g/G

FIG. D 16.7

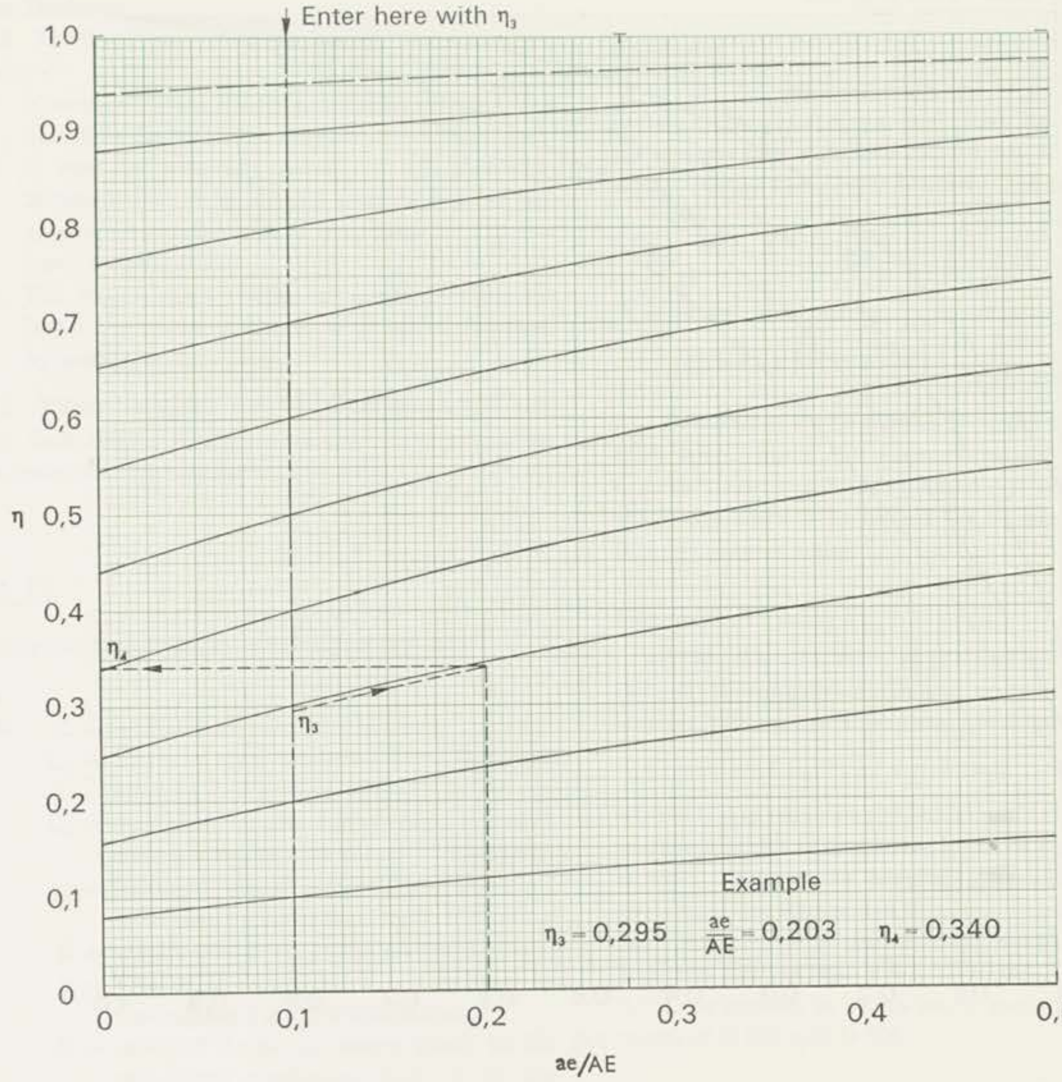

Enter here with η_3
1,0
0,9
0,8
0,7
0,6
η 0,5
0,4
0,3
0,2
0,1
0
η_4
η_3
Example
$\eta_3 = 0,295$ $\frac{ae}{AE} = 0,203$ $\eta_4 = 0,340$
0
0,1
0,2
0,3
0,4
0,5
ae/AE

FIG. D 16.8

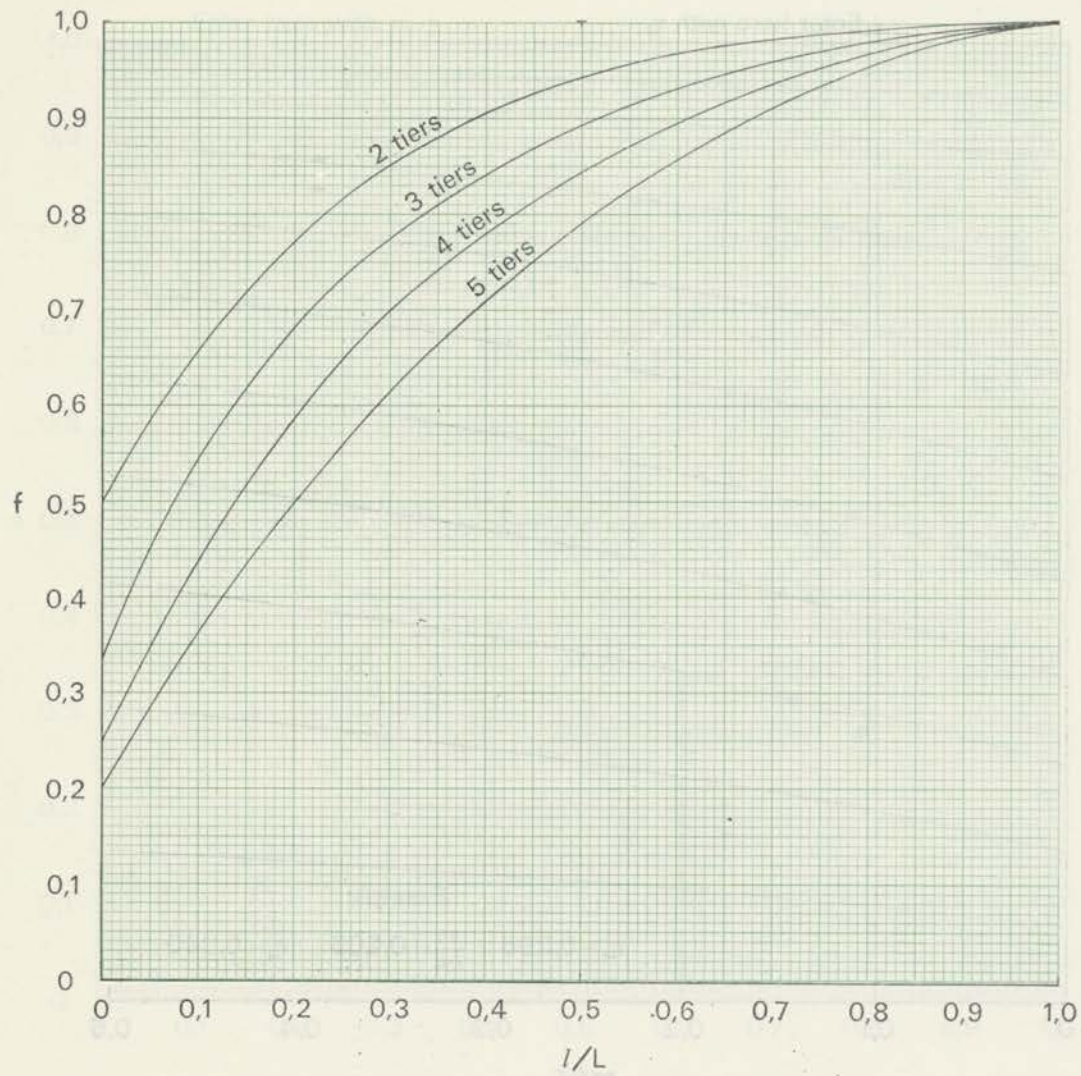

1,0
0,9
0,8
0,7
0,6
f
0,5
0,4
0,3
0,2
0,1
0
0
0,1
0,2
0,3
0,4
0,5
0,6
0,7
0,8
0,9
1,0
l/L
2 tiers
3 tiers
4 tiers
5 tiers

FIG. D 16.9

Maximum P Values

1609 In Fig. D 16.4 the ordinate P of the straight lines joining P_D, P_R and P_{BR} at any point must not exceed:—

1,0 for mild steel,
1,5 for aluminium alloy,
$\frac{1,0}{k}$ for higher tensile steel, where k is as defined in D 65.

Minimum Thickness

1610 The thickness of deck plating is to be determined as follows:—

(a) If erection efficiency factor = 0 then the thickness should be derived from D 1708.

(b) If erection efficiency factor = 1,0 then the thickness should be derived from D 403 for the uppermost erection deck, and from D 412 for lower erection decks.

(c) For intermediate values of erection efficiency factor, the minimum thickness should be obtained by interpolation.

1611 Where erections are transversely framed, the minimum deck thickness will be considered in association with the maximum sagging stress. (*See* D 3).

Section 17

SUPERSTRUCTURES AND DECKHOUSES

Symbols

1701 L = length of ship, in metres (feet).

L_1 = length of ship, in metres (feet), but need not be taken greater than 215 m (705 ft).

L_2 = length of ship, in metres (feet), but need not be taken greater than 250 m (820 ft).

L_3 = length of ship, in metres (feet), but is not to be taken greater than 160 m (525 ft).

B = moulded breadth, in metres (feet).

b = breadth of deckhouse, in metres (feet), at the bulkhead under consideration.

D = moulded depth, in metres (feet), to the uppermost continuous deck or to the deck next above a height of 1,6d from the base line amidships, whichever is the lesser.

d = moulded draught, in metres (feet).

C_b = block coefficient and is not to be taken as less than 0,68.

s = spacing of beams or stiffeners, in mm (inches).

t = thickness of plating, in mm (inches).

$$E_1 = \frac{L - 50}{20\,(D-d)} + 3{,}3$$

but need not be taken greater than 5,55.

or in British units:—

$$E_1 = \frac{L - 164}{100\,(D-d)} + 0{\cdot}65$$

but need not be taken greater than 1·10.

Forecastles

1702 All seagoing ships are to be fitted with forecastles or increased sheer, such that the distance between the summer load waterline and the top of the exposed deck at side (at the fore perpendicular) is not less than:—

$$56\,L_2\left(1 - \frac{L_2}{500}\right)\left(\frac{1{,}36}{C_b + 0{,}68}\right)\ \text{mm}$$

or in British units:—

$$0{\cdot}672\,L_2\left(1 - \frac{L_2}{1640}\right)\left(\frac{1{\cdot}36}{C_b + 0{\cdot}68}\right)\ \text{in}$$

Forecastles are to extend from the stem to a point at least 0,07L abaft the forward perpendicular, or if the required bow height is obtained by means of increased sheer, the sheer is to extend for at least 0,15L from the forward perpendicular.

Side and End Plating

1703 The thickness of the fore ends, sides and after ends of all superstructures and deckhouses (except those forming exposed machinery casings) is not to be less than:—

$$t = E_1\,R_1\,\sqrt{s}\ \text{mm (in)}$$

where R_1 is given in Tables D 17.1 and D 17.2; but in no case is a poop, bridge or deckhouse front, on the deck to which D is measured, nor the exposed after end of a deckhouse situated at the after end of this deck, to have a thickness less than 6,5 mm (0·26 in). Plating elsewhere is to have a thickness not less than 5 mm (0·20 in). The sides of bridges 0,15L, or greater, in length are to comply with the requirements of D 501 and D 505.

Side and End Stiffeners

1704 The modulus of stiffeners on the fronts, sides and after ends of all superstructures and deckhouses (except on exposed machinery casings or where frames are required by D 707) is not to be less than:—

$$\frac{I}{y} = \frac{E_1\,R_2\,s\,L_1}{600}\ \text{cm}^3\ (\text{in}^3)$$

where R_2 is given in Tables D 17.1 and D 17.2.

TABLE D 17.1

Erections on the deck to which D is measured (*See* 1701).	R_1	R_2	
	Metric and British units	Metric units	British units
Fore ends of bridges. Fore ends of poops where no bridge or large midship deckhouse is fitted.	0,072	0,487	1·16
Fore ends of poops where a bridge or large midship deckhouse is fitted.	0,063	0,122	0·29
Fore ends of midship deckhouses. Fore ends of after deckhouses where no bridge or large midship deckhouse is fitted.	$0{,}063+\frac{0{,}009b}{B}$	$0{,}122+\frac{0{,}365b}{B}$	$0\cdot29+\frac{0\cdot87b}{B}$
Fore ends of after deckhouses where a bridge or large midship deckhouse is fitted.	$0{,}053+\frac{0{,}01b}{B}$	0,122	0·29
Sides of bridges less than 0,15L in length and of poops.	$0{,}054+\frac{L_1}{7620}$ $\left(0\cdot054+\frac{L_1}{25\,000}\right)$ British	Modulus to be determined from D 707 and D 709	
Sides of forecastles but S in 1703 is not to be taken less than 700 mm (27·5 in).	$0{,}06+\frac{L_1}{7620}$ $\left(0\cdot06+\frac{L_1}{25\,000}\right)$ British	Modulus to be determined from D 707 and D 709	
Sides of deckhouses.	$0{,}055+\frac{0{,}01b}{B}$	0,105	0·25
After ends of bridges, forecastles and midship deckhouses.	0,052	$0{,}084-\frac{L_3}{3190}$	$0\cdot2-\frac{L_3}{4400}$
After ends of after deckhouses.	0,065	0,210	0·50

TABLE D 17.2

<table>
<tr><td rowspan="2">Erections on decks above that to which D is measured (See 1701).</td><td>R_1</td><td colspan="2">R_2</td></tr>
<tr><td>Metric and British units</td><td>Metric units</td><td>British units</td></tr>
<tr><td>Fronts of second tier erections.</td><td>88% of first tier values of R_1</td><td colspan="2">37% of first tier value of R_2
Minimum 0,055 | Minimum 0·13</td></tr>
<tr><td rowspan="2">Sides and after ends of second tier erections.</td><td rowspan="2">88% of first tier values of R_1</td><td colspan="2">50% of first tier values of R_2
Minimum 0,055 | Minimum 0·13</td></tr>
<tr><td colspan="2">For superstructures, see D 707 and D 709</td></tr>
<tr><td rowspan="2">Fronts, sides and after ends of third and subsequent tiers.</td><td rowspan="2">All values of R_1 may be reduced by a further 6% of the first tier value for each tier above the second.</td><td colspan="2">37% of second tier values of R_2
Minimum 0,042 | Minimum 0·10</td></tr>
<tr><td colspan="2">For superstructures, see D 707 and D 709</td></tr>
</table>

1705 When an erection exceeds 2,6 m (8·5 ft) in height, the modulus of the stiffeners is to be increased in direct proportion.

Exposed Machinery Casings

1706 Exposed machinery casings situated on the deck to which D is measured (*see* 1701) are to have plating thicknesses 15 per cent greater than those required for superstructures in the same positions.

Where such casings are situated at the after end of the ship the modulus of the stiffeners is not to be less than:—

$$\frac{I}{y} = \frac{E_1 R_2 s L_1}{600} \text{ cm}^3 \text{ (in}^3\text{)}$$

where R_2 has the following values:—

Forward ends of casings	0,633 (1·51 British)
Sides of casings	0,341 (0·81 British)
After ends of casings	0,487 (1·16 British)

When the casings on this deck are situated amidships, the modulus of the stiffeners is to be not less than 50 per cent in excess of that required for superstructures in the same position.

1707 Exposed machinery casings forming part of second or higher tiers of superstructures or deckhouses, are to have plating thicknesses 10 per cent in excess of those required for deckhouses in the same position and stiffeners with a modulus 20 per cent in excess of that required for deckhouses in the same position.

Deck Plating

1708 The thickness of deck plating is to be in accordance with the requirements of D 16 where applicable but is not to be less than:—

$$t = \left(\frac{N_1 L}{1000} + N_2\right) E_2 \sqrt{\frac{s}{N_3}} \text{ mm (in)}$$

where N_1, N_2, N_3 and E_2 are given in Table D 17.3.

1709 When decks are fitted with approved sheathing, the thicknesses derived from 1708 may be reduced in accordance with D 420.

The thicknesses, after reduction for sheathing, may be reduced by a further 10 per cent within the line of openings on exposed decks other than forecastles. Inside deckhouses the thickness may be reduced by a further 10 per cent.

Beams

1710 Transverse deck beams on the lowest tier of erections, other than forecastles, less than 0,15L in length, and on the second tier of erections when the lowest tier is 0,15L or more in length, are to have a modulus not less than:—

$$\frac{I}{y} = \frac{l\,s}{1420}(2{,}5l + 0{,}115L_1 - 4{,}5) \text{ cm}^3$$

$$\left(\frac{I}{y} = \frac{l\,s}{3000}\left(0{\cdot}76l + 0{\cdot}035L_1 - 4{\cdot}5\right) \text{ in}^3\right)$$

where l = span of beam, in metres (feet), but is not to be taken as less than 3,05 m (10 ft).

TABLE D 17.3

	Metric units	British units
N_1 forecastles N_1 erections other than forecastles	17,5 12,5	0·21 0·15
N_2 tops of erections on the deck to which D has been measured (*See* 1701) N_2 tops of second tier erections N_2 tops of third and higher tiers of erections	5,5 5,0 4,5	0·216 0·197 0·177
N_3 forward of 0,2L from forward perpendicular	frame spacing in mm (inches) as required by D 705 and D 706.	
N_3 elsewhere	760	30
$E_2 = 0{,}895 + \left(\dfrac{0{,}064 + 0{,}0021L}{D - d}\right)$ $\left(E_2 = 0{\cdot}895 + \left(\dfrac{0{\cdot}21 + 0{\cdot}0021L}{D - d}\right) \text{British}\right)$	E_2 is not to be taken less than 0,95 nor more than 1,05	

If there is no superimposed erection on the deck being supported, the modulus derived above may be reduced by 20 per cent.

1711 The beams of the tier next above that specified in 1710 are to have a modulus not less than 80 per cent of that required by 1710. The beams of the second and subsequent tier above that specified in 1710 are to have a modulus not less than 60 per cent of that required by 1710.

Strengthening at Ends and Sides of Erections

1712 Web frames or partial bulkheads are to be fitted within bridges and poops which have large deckhouses or other erections above.

Web frames or equivalent strengthening are also to be arranged to support the sides and ends of large deckhouses. These web frames should be spaced about 9 m (29·5 ft) apart and are to be arranged, where practicable, in line with watertight bulkheads below. Webs are also to be arranged in way of large openings, boat davits and other points of high loading.

1713 Arrangements are to be made to minimise the effect of discontinuities in erections. All openings cut in the sides should be substantially framed and have well rounded corners. Continuous coamings or girders are to be fitted below and above doors and similar openings. House tops are to be strengthened in way of davits.

1714 Attention is to be given to the structure at the corners and ends of erections.

Adequate support under the ends is to be provided in the form of webs, pillars, diaphragms or bulkheads in conjunction with reinforced deck beams. Deckhouses should be connected to the deck by tee bars, or similar arrangement, at the corners of the houses and in way of supporting structures.

1715 The thickness of the upper deck sheerstrake is to be increased by 50 per cent and the deck stringer plate by 25 per cent at the ends of bridges having a length of 0,15L or greater. Similar strengthening is to be fitted at the ends of poops or forecastles within 0,5L amidships.

At the ends of bridges shorter in length than 0,15L, the increases in thickness are to be 30 per cent and 10 per cent respectively.

The side plating of bridges having a length of 0,15L or greater, is to be increased in thickness by 25 per cent at the ends of the structure and is to be tapered into the upper deck sheerstrake. This plating is to be efficiently stiffened at the upper edge and supported by web plates not more than 1,5 m (5 ft) from the end bulkhead.

End Connections of Deckhouse Stiffeners

1716 The end connections of stiffeners are to be as given in Table D 17.4.

TABLE D 17.4

Position	Attachment at top and bottom
1. Front stiffeners of lower tiers and on upper tiers when L is 160 m (525 ft) or greater.	*See* Table D 32.1, Note 6.
2. Front stiffeners on upper tiers when L is less than 160 m (525 ft).	Unattached.
3. Side stiffeners on lower tiers where two or more tiers are fitted.	Bracketed, unless stiffener modulus is increased by 20 per cent and ends are welded to the deck all round.
4. Side stiffeners if only one tier is fitted and aft end stiffeners of after deckhouses on deck to which D is measured. (*See* 1701).	*See* Table D 32.1, Note 6.
5. Side stiffeners on upper tiers when L is 160 m (525 ft) or greater.	*See* Table D 32.1, Note 6.
6. Side stiffeners on upper tiers when L is less than 160 m (525 ft).	Unattached.
7. Aft end stiffeners except as covered by 4 above.	Unattached.

End Connections of Exposed Machinery Casing Stiffeners

1717 The end connections of stiffeners are to be as given in Table D 17.5.

Aluminium Deckhouses

1718 When an aluminium alloy complying with P 12 is used in the construction of deckhouses, the scantlings of these erections are to be increased (relative to those required for steel construction) by the percentages given in Table D 17.6.

The thickness of aluminium alloy stiffening members is not to be less than:—

$$t = 2{,}5+0{,}022h \text{ mm} \quad (t = 0{\cdot}10+0{\cdot}022h \text{ in}) \qquad (1)$$

where h = depth of the section, in mm (in), but need not exceed 330 mm (13 in).

The minimum moment of inertia of aluminium alloy stiffening members is not to be less than:—

$$I = 5{,}25\frac{I}{y}l \text{ cm}^4 \quad \left(I = 0{\cdot}63\frac{I}{y}l \text{ in}^4\right) \qquad (2)$$

where l is the span of the member, in metres (feet), and $\frac{I}{y}$ is the section modulus of the stiffener and attached plating.

1719 Where aluminium erections are arranged above a steel hull, details of the arrangements in way of the bi-metallic connection are to be submitted.

TABLE D 17.5

Position	Attachment at top and bottom
1. Front stiffeners on amidship casings and all stiffeners on aft end casings which are situated on the deck to which D is measured. (*See* 1701).	Bracketed.
2. All other stiffeners on casings.	6,5 cm^2 (1·0 in^2) of weld.

TABLE D 17.6

Item	Percentage Increase
Fronts, sides, after ends and unsheathed deck plating.	20
Decks sheathed in accordance with D 420.	10
Decks sheathed with wood and on which the plating is fixed to the wood sheathing at the centre of each beam space.	Nil
Stiffeners and beams	70
Scantlings of small isolated houses.	Nil

Cross-references

1720 For the effect of erections on longitudinal strength, *see* D 16.

For superstructure side frames, deck longitudinals and beams, *see* D 7, D 6 and D 8 respectively.

For connections to the sheerstrake, *see* D 510.

For aluminium deckhouses, *see also* F 812.

Section 18

WATERTIGHT BULKHEADS

Symbols

1801

a = height, in metres (feet), of bracket or end stool or lowest strake of plating.

e = effective length, in metres (feet), of bracket or end stool, as given in Tables D 18.2 and D 18.3.

h, h_0 = vertical distance, in metres (feet), from the middle of span l, S, respectively, to a point 0,91 m (3 ft) above the bulkhead deck at side.

$l = S - e_1 - e_2$
= effective span, in metres (feet), of stiffener or corrugation, (*see* Figs. D 18.1 and D 18.2).

S = overall height, in metres (feet), of bulkhead between support points (including brackets or end stools if fitted).

γ = 1,4 for double plate bulkheads and welded stiffeners other than flat bars,
1,6 for flat bar stiffeners and swedges,
1,1 for symmetrical corrugations.

ω = end constraint coefficient relating to the ends of the effective span l. Values of ω lie between 0 and 1.

L_1 = length of ship, in metres (feet), but need not be taken greater than 215 m (705 ft).

Number and Disposition of Transverse Bulkheads

1802 All ships are to have a collision bulkhead situated not less than $0{,}05L_1$ nor more than $0{,}075L$ from the fore end of the load waterline, an after peak bulkhead enclosing the stern tubes in a watertight compartment and a bulkhead at each end of the machinery space.

1803 Additional watertight bulkheads are to be fitted so that the total number of bulkheads is in accordance with Table D 18.1.

1804 The bulkheads in the holds should be spaced at reasonably uniform intervals. Where this is departed from and the length of a hold is unusually great, the transverse strength of the ship is to be maintained.

1805 The Committee will be prepared to consider proposals from owners to dispense with one or more of these bulkheads if they interfere with the requirements of a special trade, subject to suitable structural compensation.

Height of Bulkheads

1806 The collision bulkhead is to extend to the uppermost continuous deck.

1807 The after peak bulkhead may terminate at the first deck above the load waterline, provided this deck is made watertight to the stern or to a watertight transom floor.

TABLE D 18.1

Length L				Total number of bulkheads	
Above		Not exceeding		Machinery amidships	Machinery aft*
Metres	Feet	Metres	Feet		
90	295·0	105	344·5	5	5
105	344·5	115	377·3	6	5
115	377·3	125	410·1	6	6
125	410·1	145	475·7	7	6
145	475·7	165	541·3	8	7
165	541·3	190	623·4	9	8
190	623·4			To be considered individually.	

*After peak bulkhead forming the after boundary of the machinery space.

1808 The remaining bulkheads are to extend to the uppermost continuous deck except where the draught is not greater than that permitted with a superstructure extending for the full length of the ship above the second deck, when the bulkheads may terminate at that deck provided it lies above the load waterline.

In passenger ships of restricted draught, the height of the bulkhead will be specially considered.

Bulkhead Plating

1809 The thickness of plating of watertight bulkheads which do not form the boundaries of tanks is not to be less than:—

$$t=0{,}004\ s\sqrt{h_1}\ \text{mm}\ \left(t=0{\cdot}0022\ s\sqrt{h_1}\ \text{in}\right)$$

unless $\frac{1000S_1}{s}$ $\left(\frac{12S_1}{s}\text{ British}\right)$ is less than 4, when the thickness obtained from the above formula is to be multiplied by the factor $1{,}1-\frac{s}{2500S_1}$ $\left(1{\cdot}1-\frac{s}{30S_1}\text{ British}\right)$

where s = (i) stiffener spacing, in mm (in), on plane or double plate bulkheads,

(ii) breadth, in mm (in), of flange or web, whichever is the greater, for corrugated bulkheads,

(iii) breadth of flat plating, in mm (in), for swedged bulkheads,

h_1 = vertical distance, in metres (feet), from a point one third of the height of the plate above its lower edge, to a point 0,91 m (3 ft), above the bulkhead deck at side,

S_1 = overall length of stiffener between support points, in metres (feet).

The thickness of collision bulkheads not forming the boundaries of tanks is to be 12 per cent greater than the thickness derived from the formula above.

The minimum thickness of bulkhead plating is to be 5,5 mm (0·22 in). Where the class notation includes a reference to ore cargoes the minimum thickness of the hold bulkheads is to be 10 mm (0·40 in).

Bulkhead Stiffeners

1810 The scantlings of stiffeners of watertight bulkheads not forming boundaries of tanks, are to be determined from 1814 for rolled or built stiffeners and swedges and from 1815 for symmetrical corrugations and double plate bulkheads.

The section modulus of stiffeners of collision bulkheads not forming the boundaries of tanks is to be 25 per cent greater than that required for watertight bulkheads.

1811 Where bulkhead stiffeners are cut in way of watertight doors in the lower part of a bulkhead, the opening is to be suitably framed and reinforced.

Where stiffeners are not cut but the spacing between the stiffeners is increased on account of watertight doors, as in 'tween deck bulkheads, the stiffeners at the sides of the doorways are to be increased in depth and strength so that the efficiency is at least equal to that of the unpierced bulkhead, without taking the stiffness of the door frame into consideration.

1812 Bulkheads are to be suitably strengthened, if necessary, at the ends of deck girders and where subjected to concentrated loads.

1813 The section modulus of swedges is to be calculated in association with 610 mm (24 in) or the breadth of flat plating, whichever is the lesser.

TABLE D 18.2

ROLLED OR BUILT STIFFENERS AND SWEDGES

End Connection (*see* Fig. D 18.1)			Type	ω	e
End of stiffener unattached or attached to plating only			(1)	0	0
Member in line at deck or at Rule horizontal girder	Adjacent member B of smaller section		(2)	$\frac{4{,}5}{M_1}\left(\frac{I}{y}\right)_B$ or 1*	0
	Adjacent member B of same or larger section		(3)	1	0
Bracketless connection to longitudinal member	Member A within length S		(4)	1	d_A
	Member A outside length S		(5)	1	0
Bracketed	To transverse member	Bracket extends to floor	(6)	1	βa or 0,1S*
		Otherwise	(7)	1	0
	To longitudinal member		(8)	1	βa or 0,1S*

where $\beta = 1$ for brackets with face bars directly connected to stiffener face bars,
0,7 for flanged brackets,
0,5 for unflanged brackets,

d_A = depth, in metres (feet), of supporting member A (*see* Fig. D 18.1),

$\left(\frac{I}{y}\right)_B$ = section modulus, in cm^3 (in^3), of supporting member B,

$$M_1 = \frac{h\,s\,l^2}{71} \quad \left(\frac{h\,s\,l^2}{1620} \text{ British}\right)$$

*Where two values of ω or e are given in the Table, the smaller is to be used.

Rolled or Built Stiffeners and Swedges

1814 The section modulus of rolled or built stiffeners and swedges, calculated at the middle of span l on watertight bulkheads not forming boundaries of tanks is not to be less than:—

$$\frac{I}{y} = \frac{h\,s\,l^2}{71\,\gamma\,(\omega_1+\omega_2+2)}\ \text{cm}^3 \quad \left(\frac{h\,s\,l^2}{1620\,\gamma\,(\omega_1+\omega_2+2)}\ \text{in}^3\right)$$

where s = spacing of stiffeners, in mm (in).

The ratio of the web depth to the web thickness is not to exceed 60 for stiffeners with flanges or face plates and 18 for flat bars.

NOTES:—

(1) Various types of end connection are listed in Table D 18.2 and illustrated in Fig. D 18.1 for the corresponding type number, together with appropriate values of end constraint ω and, where applicable, effective bracket length e. Suffixes 1 and 2 refer to top and bottom of stiffener respectively.

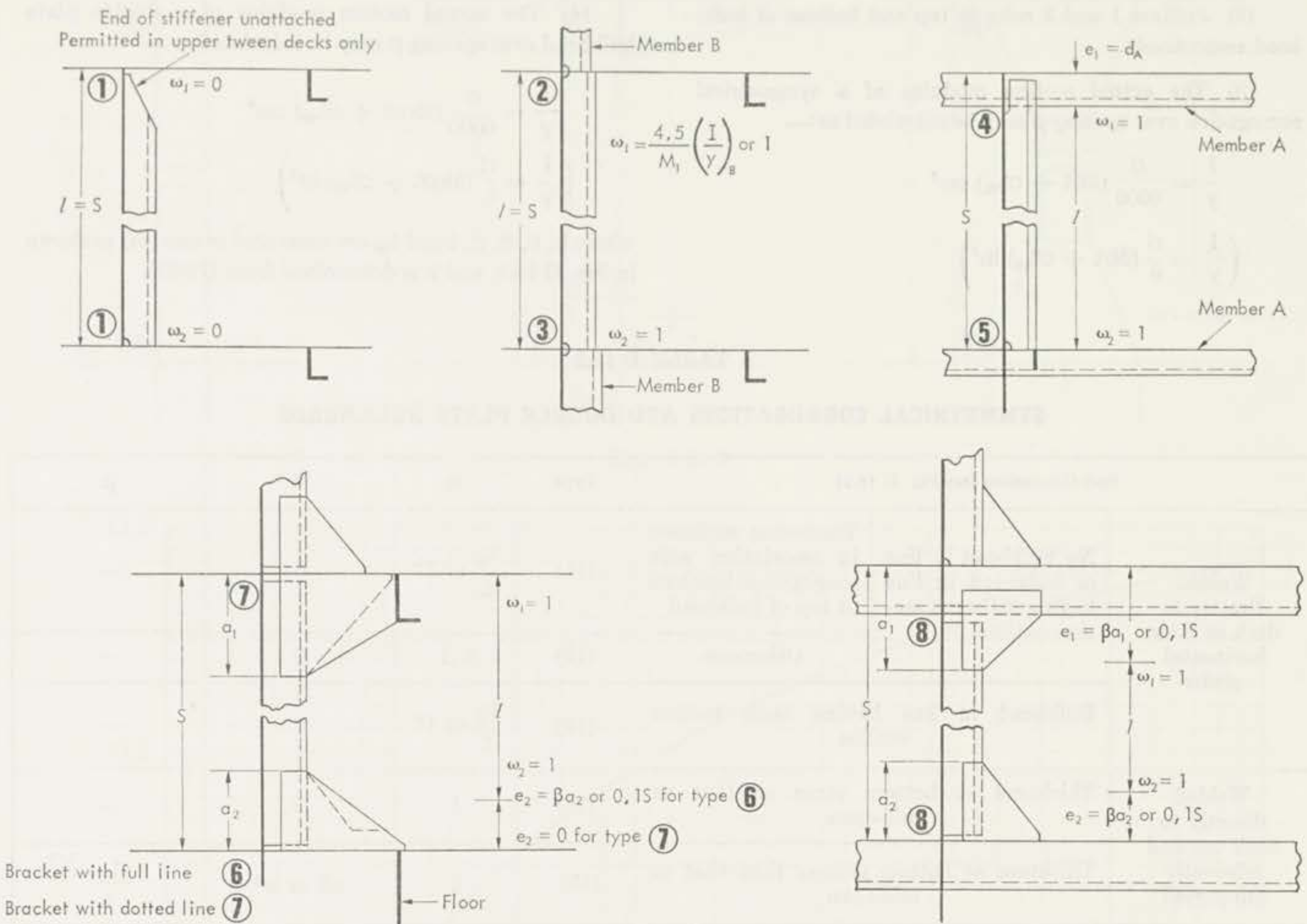


FIG. D 18.1

(2) When a bulkhead consists of several spans of vertical stiffeners supported by 'tween decks or horizontal girders, it is recommended that the top span should be calculated first and then the other spans considered from the top span downwards.

(3) For convenience of definition, Table D 18.2 implies vertical stiffening on transverse bulkheads. The Rules also apply to horizontal stiffening and longitudinal bulkheads, providing due regard is paid to the appropriate directions of end supporting members.

(4) Bracketless connections type (4) may be made by welding the stiffening members "back to back" with as large an overlap as possible, or with the flanges on the same side, provided the web at the corner of the connection is suitably strengthened with a doubling plate or a diagonal stiffener.

Symmetrical Corrugations and Double Plate Bulkheads

1815 The section modulus of symmetrical corrugations and double plate bulkhead primary members, calculated at the middle of span l on watertight bulkheads not forming boundaries of tanks, is not to be less than:—

$$\frac{I}{y} = \frac{h\,p\,l^2}{71\,\gamma\,(\omega_1+\omega_2+2)}\ \text{cm}^3$$

$$\left(\frac{I}{y} = \frac{h\,p\,l^2}{1620\,\gamma\,(\omega_1+\omega_2+2)}\ \text{in}^3\right)$$

where p is the spacing of corrugations or vertical webs of double plate bulkheads (*see* Fig. D 18.4).

NOTES:—

(1) Various types of end connection are listed in Table D 18.3 and illustrated in Fig. D 18.2 for the corresponding Type number, together with appropriate values of end constraint ω and, where applicable, effective stool length e.

(2) Suffixes 1 and 2 refer to top and bottom of bulkhead respectively.

(3) The actual section modulus of a symmetrical corrugation over spacing p may be calculated as:—

$$\frac{I}{y} = \frac{d}{6000}(3bt + ct_w) \text{ cm}^3$$

$$\left(\frac{I}{y} = \frac{d}{6}(3bt + ct_w) \text{ in}^3\right)$$

(4) The actual section modulus of a double plate bulkhead over spacing p may be calculated as:—

$$\frac{I}{y} = \frac{d}{6000}(6kpt + dt_w) \text{ cm}^3$$

$$\left(\frac{I}{y} = \frac{d}{6}(6kpt + dt_w) \text{ in}^3\right)$$

where b, c, d, p, t and t_w are measured in mm (in) as shown in Fig. D 18.4, and k is determined from D 5304.

TABLE D 18.3

SYMMETRICAL CORRUGATIONS AND DOUBLE PLATE BULKHEADS

End Connection (*see* Fig. D 18.2)			Type	ω	e	μ
Welded directly to deck or Rule horizontal girder	No bulkhead in line or bulkhead in line having different section outline	Transverse stiffeners in association with longitudinal brackets at top of bulkhead	(11)	$\frac{t_e}{t}$ or 1*	0	—
		Otherwise	(12)	0,1	0	—
	Bulkhead in line having same section outline		(13)	$\frac{t_B}{t}$ or 1*	0	—
Welded directly to tank top and efficiently supported	Thickness at bottom same as that at mid-span		(14)	1	0	—
	Thickness at bottom greater than that at mid-span		(15)	1	αS or a*	$\frac{t_e}{t}$
Welded to stool efficiently supported by ship structure			(16)	1	αS or a*	$\frac{10}{M_2}\left(\frac{I}{y}\right)_S$

where t, t_e = thickness, in mm (in), of flange plating of corrugation or double plate bulkhead, at mid-span or end respectively,

t_B = thickness, in mm (in), of flange plating of member B,

α = coefficient given in Fig. D 18.3,

$\left(\frac{I}{y}\right)_S$ = modulus, in cm³ (in³), of horizontal section of stool adjacent to deck or tank top over breadth p. All material continuous from top to bottom of the stool may be included in the calculation,

$$M_2 = \frac{h_o p S^2}{71} \quad \left(M_2 = \frac{h_o p S^2}{1620} \text{ British}\right)$$

*Where two values of ω or e are given in the Table the smaller is to be used.

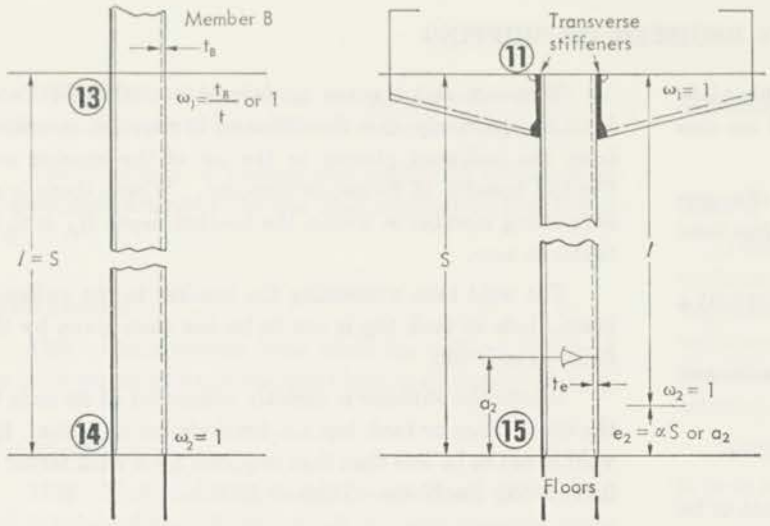


FIG. D 18.2

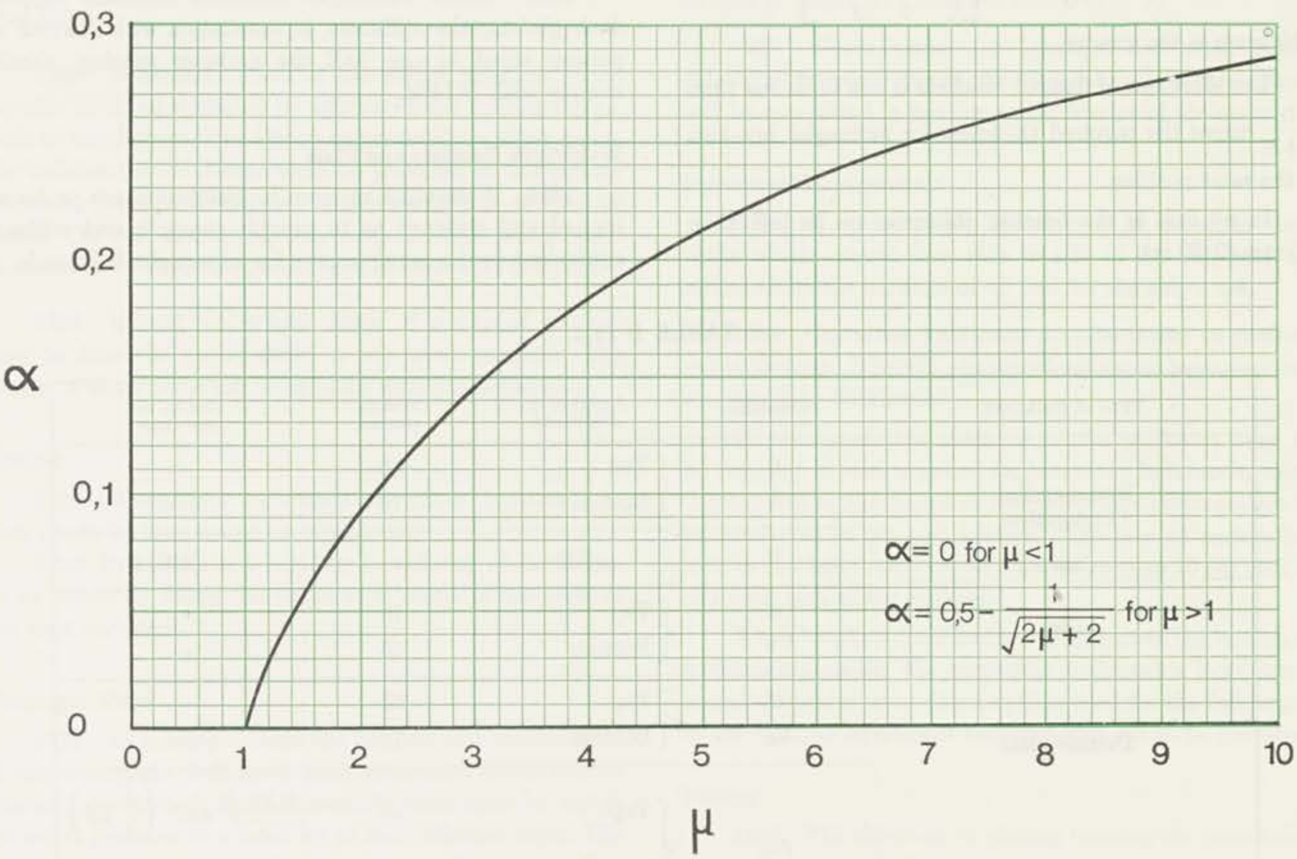


FIG. D 18.3

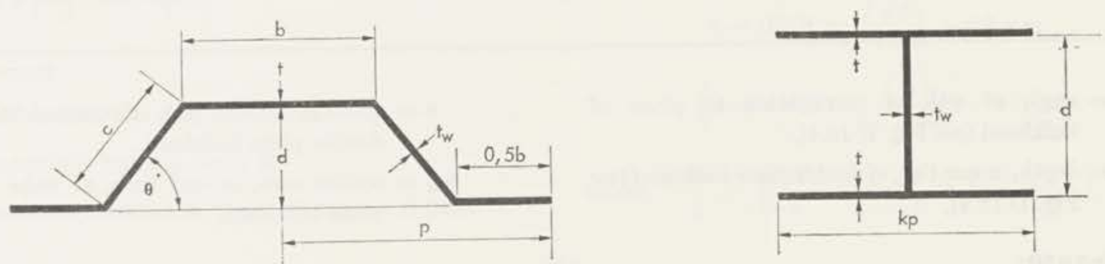


FIG. D 18.4

1816 For symmetrical corrugations and double plate bulkheads, the requirements given in Table D 18.4 are also to be complied with.

The plating thickness at the middle of span l of corrugated and double plate bulkheads is to extend not less than $0{,}2l$ metres (feet) above mid-span.

Where the span of corrugations exceeds 15 m (49 ft) a diaphragm is to be arranged at about mid-span.

Manholes and lightening holes should not be positioned at the ends of webs in double plate bulkheads.

End Connections

1817 The thickness of unflanged brackets is not to be less than the stiffener web thickness or

$$16{,}7\,(a - d_A)\ \text{mm} \quad \left[\left(\frac{a - d_A}{5}\right)\ \text{in}\right]$$

whichever is the greater.

The thickness of flanged brackets is not to be less than $\frac{b}{b+3f}$ times the required thickness for unflanged brackets in the same position.

In no case is the bracket thickness to be less than 7,5 mm (0·30 in).

Where a and d_A are as defined in 1801 and Table D 18.2 respectively, b is the distance, in mm (in), measured from the bulkhead plating to the toe of the bracket and f is the breadth of flange, in mm (in). Where there is no supporting member A within the bracket depth d_A is to be taken as zero.

The weld area connecting the bracket to the stiffener, beam, deck or tank top is not to be less than given by the formulæ in D 733.

Where the stiffener is directly connected at its ends to the deck, beam or tank top, i.e. brackets are not fitted, the weld is not to be less than that required for a weld factor of 0,44 (0·63). *See* Notes—Table D 32.1.

Stiffeners supporting Girders

1818 Where watertight bulkhead stiffeners support deck girders, the stiffeners, in association with a width of plating equal to one half the stiffener spacing, should comply with D 1402.

Watertight Recesses and Flats

1819 Watertight recesses in bulkheads are to be so framed and stiffened as to provide strength and stiffness equivalent to the requirements for watertight bulkheads.

TABLE D 18.4

Type of Bulkhead	Parameter	Position in Bulkhead	Not to exceed	Not to be less than
Symmetrical Corrugation	$\frac{b}{t}$	Top	85	—
		Bottom	70	—
	θ	All	—	40°
Double plate	$\frac{s}{t}$	Top	75	—
		Bottom	65	—
	$\frac{d}{t_w}$	Top	85	—
		Bottom	75	—
	A_w	Top	—	$\frac{0{,}12\,\frac{I}{y}}{l}$ cm² $\left(\frac{\frac{I}{y}}{l}\ \text{in}^2\right)$
		Bottom	—	$\frac{0{,}18\frac{I}{y}}{l}$ cm² $\left(\frac{1{\cdot}5\frac{I}{y}}{l}\ \text{in}^2\right)$

where θ = angle of web of corrugation to plane of bulkhead (*see* Fig. D 18.4),

d = depth, in mm (in), of double plate bulkhead (*see* Fig. D 18.4),

s = spacing, in mm (in), of vertical stiffeners of double plate bulkhead,

A_w = section area, in cm² (in²), of webs of double plate bulkhead.

1820 Horizontal plating is to be 1 mm (0·04 in) thicker than required by 1809 at a corresponding level.

The thickness of plating and scantlings of beams or longitudinals are not to be less than required by D 4, D 8 or D 6.

Chain Lockers

1821 Chain lockers fitted abaft the collision bulkhead are to be watertight and the space is to be efficiently drained.

Watertight Doors

1822 Watertight doors are to be efficiently constructed and fitted, and should be capable of being operated when the ship is listed up to 15 degrees either way. They are to be operated under working conditions and hose tested in place. (*See* 1826).

1823 Watertight doors of the sliding type are to be capable of being operated by efficient hand operated gear, both at the door itself and from an accessible position above the bulkhead deck. Means shall be provided at the remote operating position to indicate whether the door is open or closed. The lead of shafting is to be as direct as possible and the screw is to work in a gunmetal nut. (*See also* D 2001).

1824 Hinged watertight doors of approved pattern may be fitted in 'tween decks in approved positions. The hinges of these doors are to be fitted with gunmetal pins.

Testing

1825 Watertight bulkheads including recesses and flats are to be hose tested on completion.

Peak bulkheads not forming boundaries of tanks are to be tested by filling the peaks with water to the level of the load waterline.

Passenger Ships

1826 In passenger ships the number and construction of the watertight bulkheads and watertight doors will be specially considered. Each watertight door shall be tested by water pressure to a head up to the bulkhead deck. The test may be carried out either before or after the door is fitted. (*See* F 801 and F 805).

Cross-references

1827 For peak and deep tanks, *see* D 19.

For watertight tunnels, *see* D 20.

For machinery casings in 'tween decks, *see* D 2109.

Section 19

PEAK, DEEP AND TOPSIDE TANKS

General

1901 This section gives the required scantlings for tanks carrying water, oil fuel for ship's use, or oil (including vegetable oil) and other liquids carried as cargo. When boundary bulkheads form part of the watertight sub-division of the ship the requirements of D 18 are also to be satisfied.

1902 The scantlings of fore and after peak tanks are to be in accordance with sections D 54 and D 55 respectively.

1903 The close test flash point (as determined by a standard type of flash point apparatus) of oil fuel, or oil carried as cargo, is to be above 65,5°C (150°F).

1904 Where tanks are intended for other liquid cargoes of a special nature the scantlings and arrangements will be considered in relation to the nature of the cargo.

Structural Arrangements

1905 A centreline bulkhead is to be fitted in deep tanks which extend from side to side of the ship and are intended for the carriage of oil fuel for the ship's use.

1906 Centreline bulkheads may be intact or perforated as desired. If intact, the scantlings are to be as required for boundary bulkheads.

If perforated, the modulus of the stiffeners may be 50 per cent of that required for boundary bulkheads, using h measured to the crown of the tank. The stiffeners are to be bracketed at top and bottom. The area of perforation is to be not less than 5 per cent nor more than 10 per cent of the total area of the bulkhead.

When brackets from horizontal girders on the boundary bulkheads abut on the centreline bulkhead a light intercostal stringer is to be fitted at that level for the full length of the tank, or equivalent arrangements are to be provided.

Plating

1907 The thickness of plating forming the boundaries of tanks is not to be less than:—

$$t = 0{,}004\, s \sqrt{\frac{\rho\, h_2}{1{,}025}} + 2{,}5 \text{ mm}$$

$$\left(t = 0{\cdot}0022\, s \sqrt{\frac{\rho\, h_2}{1{\cdot}025}} + 0{\cdot}1 \text{ in}\right)$$

unless $\frac{1000 S_1}{s}$ $\left(\frac{12 S_1}{s} \text{ British}\right)$ is less than 4, when the

thickness obtained from the above formula is to be multiplied by the factor:—

$$1{,}1 - \frac{s}{2500 S_1} \quad \left(1\cdot 1 - \frac{s}{30 S_1} \text{ British}\right)$$

where s = stiffener spacing, in mm (in), on plane or double plate bulkheads, or
breadth, in mm (in), of flange or web, whichever is the greater, for corrugated bulkheads, or
breadth of flat plating, in mm (in), for swedged bulkheads,

ρ = specific gravity of the liquid to be carried and is not to be taken as less than 1,025,

h_2 = vertical distance, in metres (feet), from a point one-third of the height of the plate above its lower edge to the top of the tank or half the distance to the top of the overflow, whichever is the greater,

S_1 = overall length of stiffener between support points, in metres (feet).

The minimum thickness of plating is to be 7,5 mm (0·30 in).

Rolled or Built Stiffeners and Swedges

1908 The section modulus and inertia of rolled or built stiffeners and swedges, calculated at the middle of span l on bulkheads forming tank boundaries, is not to be less than:—

$$\frac{I}{y} = \frac{h s l^2}{21{,}5\gamma(\omega_1 + \omega_2 + 2)} \text{ cm}^3$$

$$\left(\frac{I}{y} = \frac{h s l^2}{490\gamma(\omega_1 + \omega_2 + 2)} \text{ in}^3\right)$$

$$\text{and } I = 2{,}3 \frac{I}{y} l \text{ cm}^4 \quad \left(I = 0\cdot 276 \frac{I}{y} l \text{ in}^4\right)$$

The symbols used are as defined in D 1801, D 1814 and the values of ω and e are to be derived from Table D 18.2 except that:—

h, h_o = vertical distance, in metres (feet), from the middle of span l, or S respectively, to the top of the tank or half the distance, in metres (feet), from the middle of the span to the top of the overflow, whichever is the greater.

Where the specific gravity, ρ, of the liquid to be carried exceeds 1,025, the values of h and h_o are to be multiplied by the factor $\frac{\rho}{1{,}025}$

$$M_1 = \frac{h s l^2}{21{,}5} \quad \left(M_1 = \frac{h s l^2}{490} \text{ British}\right)$$

The ratio of the web depth to the web thickness is not to exceed 60 for stiffeners with flanges or face plates and 18 for flat bars.

1909 For swedges, the section modulus is to be calculated in association with 610 mm (24 in) of attached plating or the breadth of flat plating, whichever is the lesser.

End Connections

1910 Stiffener end connections are to be as required by D 1817.

NOTE:—End connections of Type (1) (*see* Fig. D 18.1) are not permitted at tank boundaries.

Symmetrical Corrugations and Double Plate Bulkheads

1911 The section modulus of symmetrical corrugations and double plate bulkhead primary members, calculated at the middle of span l on bulkheads forming tank boundaries, is not to be less than:—

$$\frac{I}{y} = \frac{h p l^2}{21{,}5\gamma(\omega_1 + \omega_2 + 2)} \text{ cm}^3$$

$$\left(\frac{I}{y} = \frac{h p l^2}{490\gamma(\omega_1 + \omega_2 + 2)}\right) \text{ in}^3$$

The symbols used are as defined in D 1801 and D 1815 and the values of ω and e are to be derived from Table D 18.3 except that h and h_o are as defined in 1908 and

$$M_2 = \frac{h_o p S^2}{21{,}5} \quad \left(M_2 = \frac{h_o p S^2}{490} \text{ British}\right)$$

The depth d of symmetrical corrugations and double plate bulkheads is not to be less than:—

$$d = 39l \text{ mm } (0\cdot 47l \text{ in})$$

1912 The section modulus of symmetrical corrugations and double plate bulkheads may be calculated as described in D 1815, Notes 3 and 4.

1913 For symmetrical corrugations and double plate bulkheads forming tank boundaries, the requirements of Table D 19.1 are also to be complied with.

The plating thickness at the middle of span l of corrugated and double plate bulkheads is to extend not less than 0,2l metres (feet) above mid-span.

Where the span of corrugations exceeds 15 m (49 ft) a diaphragm is to be arranged at about mid-span.

Manholes and lightening holes should not be positioned at the ends of webs in double plate bulkheads, unless suitable reinforcement is provided.

Girders

1914 The section modulus and moment of inertia of girders, when fitted, are not to be less than:—

$$\frac{I}{y} = 12hbS_G^2 \text{ cm}^3 \qquad \left(\frac{I}{y} = \frac{hbS_G^2}{158} \text{ in}^3\right) \qquad (1)$$

$$\text{and } I = 2{,}5\, S_G \frac{I}{y} \text{ cm}^4 \qquad \left(I = 0{\cdot}3\, S_G \frac{I}{y} \text{ in}^4\right) \qquad (2)$$

where h = vertical distance, in metres (feet), from the mid-point of length to the top of the tank or half the distance, in metres (feet), from the mid-point of length to the top of the overflow, whichever is the greater. For girders supporting side frames h is in no case to be taken as less than the distance from the girder to the upper deck at side or to a line $1{,}4d$ above the keel, whichever is the lesser.

b = distance, in metres (feet), between the centres of the two adjacent spans of stiffeners or frames supported by the girder,

d = moulded draught, in metres (feet),

S_G = span of girder, in metres (feet), measured between span points as shown in Fig. D 46.1.

Where the specific gravity, ρ, of the liquid to be carried exceeds 1,025 the value of $\frac{I}{y}$ is to be multiplied by the factor:—

$$\frac{\rho}{1{,}025}$$

1915 If girders are fitted, they are to form a continuous line of support on bulkheads and ship's side. The thickness of the girder web plate is not to be less than:—

$$t = 9 + 0{,}008 \left(\frac{d_\omega}{50}\right)^2 \text{ mm}$$

$$\left(t = 0{\cdot}35 + 0{\cdot}2 \left(\frac{d_\omega}{50}\right)^2 \text{ in}\right)$$

where d_ω = depth of web, in mm (in).

TABLE D 19.1

Type of Bulkhead	Parameter	Position in Bulkhead	Not to exceed	Not to be less than
Symmetrical Corrugations	$\frac{b}{t}$	Top	70	—
		Bottom		—
	θ	All	—	40°
Double plate	$\frac{s}{t}$	Top	75	—
		Bottom	65	—
	$\frac{d}{t_w}$	Top	85	—
		Bottom	75	—
	A_w	Top	—	$0{,}07 \frac{I/y}{l}$ cm² $\left(0{\cdot}58 \frac{I/y}{l} \text{ in}^2\right)$
		Bottom	—	$0{,}1 \frac{I/y}{l}$ cm² $\left(0{\cdot}83 \frac{I/y}{l} \text{ in}^2\right)$

where θ = angle of web of corrugation to plane of bulkhead (*see* Fig. D 18.4),

d = depth, in mm (in), of double plate bulkhead,

s = spacing, in mm (in), of vertical stiffeners of double plate bulkhead,

A_w = section area, in cm² (in²), of webs of double plate bulkhead.

They are to be connected at their ends by flanged brackets having the same thickness as the web plate of the thicker girder and a length of arm, measured from the point of the bracket to the edge of the girder, equal to the width of the wider girder. If the bracket terminates on a bulkhead the length of the arms is to be equal to the width of the girder. The ends of the brackets are to be adequately supported.

1916 The girders are to be supported by tripping brackets at the toes of the end brackets and elsewhere at every third stiffener or frame. Stiffeners or frames intermediate between these brackets are to be effectively connected to the girders.

Topside Tanks

1917 The thickness of the sloping bulkhead plating is to be as required by 1907 but h is not to be taken as less than that at the half width of the tank.

In no case is the thickness to be less than required by D 412 for second deck—outside line of openings.

When the vertical strake of plating under the hatch coaming exceeds 20,5 mm (0·80 in) in thickness it is to be of Grade D quality steel within 0,4L amidships.

1918 Particular attention is to be paid to the structural arrangements within topside tanks.

A transverse should normally be arranged in line with the ends of the main cargo hatchways and in ships exceeding 215 m (705 ft) in length, a fore and aft diaphragm extending vertically from the deck to the sloping plating of the topside tank, may be required at about the half width of the tank.

Decks

1919 The thickness of plating of a deck forming the crown of a tank is to be 1,0 mm (0·04 in) greater than that which would be required by 1907, but is not to be less than required by D 4.

1920 The section modulus of beams is not to be less than required by 1908 but is also to satisfy the requirements of D 8.

Tunnels and Recesses

1921 The scantlings and arrangements of tunnels, horizontal and longitudinal steps and recesses generally are to be equivalent to the requirements for boundary bulkheads.

Ventilators

1922 Ventilators from deep tanks passing through a 'tween deck are to be strong enough to withstand the pressure to which they may be subjected and they are to be made watertight.

Welded Connections

1923 Welded connections are to be in accordance with the requirements of Table D 32.1.

Special Requirements for Oil Fuel Tanks in Refrigerated Ships

1924 Where the hold above a double bottom tank carrying oil fuel is used for refrigerated cargo, the tank side brackets and floor plates are to be attached to the margin plate by welding, and gussets are to be welded to the margin plate. The connections of hold pillars, including heel doubling plates, also of the floors and intercostal plates under the pillars to the inner bottom, are to be welded. The attachments of manhole covers are not to pass through the inner bottom plating.

1925 For the requirements for protection of oil-tight bulkheads, decks and inner bottom in way of refrigerated holds, *see* E 345 and E 346.

Protection and Drainage in Tanks Carrying Oil Fuel or Lubricating Oil

1926 Compartments carrying oil fuel or lubricating oil are to be separated by cofferdams from those carrying fresh or feed water. Oil fuel or lubricating oil compartments are to be similarly separated from those carrying vegetable oil. Cofferdams are to be suitably ventilated.

For tanks carrying vegetable and similar oils, *see* 1931.

1927 Gutterways are to be arranged at the foot of bulkheads in boiler rooms to ensure that leakage shall have free drainage to the wells or limbers.

1928 Drip trays or gutterways with suitable draining arrangements are to be provided for all tanks which do not form part of the hull structure, at pumps, valves and elsewhere where there is a possibility of leakage. Drip trays are also to be fitted under oiltight decks, except if these are completely welded, when the drip trays need only be fitted over the boilers.

1929 If cargo is carried in a compartment adjacent to an oil fuel settling tank which may be heated, the compartment side of the bulkhead or deck is to be insulated or equivalent arrangements provided.

Tanks Carrying Vegetable and Similar Oils

1930 The ventilation, drainage and control are to be generally as required for oil fuel tanks.

1931 Deep or peak tanks carrying vegetable or similar oils are to be separated from those carrying oil fuel, lubricating oil or fresh or feed water by a cofferdam.

Cofferdams are not required between oil fuel double bottom tanks and deep tanks above provided the inner bottom plating is not subjected to a head of oil fuel.

1932 All erection holes in knees, brackets, etc., are to be closed effectively. *See* Table D 32.1, Note 5, regarding welding.

Testing

1933 Tanks are to be tested by a head of water equal to the maximum to which the tank may be subjected, but not less than 2,44 m (8 ft) above the crown of the tank.

Topside tanks are to be tested either by testing each tank in accordance with the above or water testing one tank on each side of the ship and air testing the remainder. The air test is to be in accordance with D 5202. The tanks to be water tested are to be selected by the Surveyor.

When a preservative coating is to be applied to the internal structure of a tank, the water testing may take place after the application of the preservative, provided the structure is carefully examined to ensure that all welding and structural stiffening is completed prior to the application of the coating, and any riveted shell seams are tested with a high pressure hose test on the berth before coating. The hose test of the riveted seams may be carried out from the outside to avoid wetting the tank structure. As an alternative to hose testing, a leak test as described in D 5202 would be accepted.

The cause of any discoloration or disturbance of the coating is to be ascertained and any deficiencies repaired.

The attachment of fittings to oiltight surfaces should be completed before tanks are tested.

Loading Certificates

1934 When a loading certificate is requested, before a cargo of oil is loaded the tank should be tested under pressure and examined for cleanness to ensure that it is in a proper condition to receive the oil cargo.

In special circumstances the Committee will be prepared, with the consent of all interested parties, to consider alternative arrangements in respect of the testing of these tanks.

Cross-references

1935 For side frames in deep tanks, *see* D 7.

For reductions when an approved system of corrosion control is fitted, *see* D 110.

For hatch covers, *see* D 2638.

For air and sounding pipes, *see* D 29.

For pumping and piping arrangements, *see* **Chapter E.**

Section 20

WATERTIGHT TUNNELS

Tunnels

2001 Where a machinery space is situated with a compartment or compartments between it and the after peak bulkhead the shafting is to be enclosed in a watertight tunnel large enough to permit of proper examination and repair of shafting. A sliding watertight door, capable of being operated locally on both sides of the door, is to be provided at the forward end of the tunnel. (*See* D 2113).

Pipe tunnels are to have dimensions adequate for reasonable access.

Plating

2002 The thickness of tunnel plating is to be determined from D 1809. The thickness of plating derived from D 1809 may be reduced by 10 per cent for top plating where it is well curved.

If the top of the tunnel is flat the plating is to be not less than 10 per cent thicker than required by D 1809.

2003 Under hatchways the top plating is to be increased by 2 mm (0·08 in), unless covered with wood not less than 50 mm (2 in) in thickness which is to be secured by fastenings which do not penetrate the plating.

Where it is intended to use plywood or other forms of ceiling of an approved type instead of planking, the thickness will be considered in each case.

Stiffeners and End Attachments

2004 The scantlings of stiffeners are to be determined from D 1814 taking $\omega_1 = 1$ and $\omega_2 = 1$ in the appropriate formula. The span of the stiffener l is to be taken as the overall height of the tunnel, measured vertically at the centreline of the tunnel.

Where the tunnel top is flat, scantlings of the top stiffeners are also to satisfy D 8 where appropriate.

The lower end connection to the tank top is to be welded. (*See* Table D 32.1).

Tunnels in Deep Tanks

2005 When tunnels form boundaries of deep tanks the requirements of D 19 are to be applied where appropriate.

Local Strengthening

2006 Additional strengthening is to be fitted under the heels of pillars or masts stepped on the tunnel.

The strength of bulkheads in way of watertight doors is to be maintained. (*See* D 1811).

Ventilators

2007 Tunnel ventilators are to have scantlings suitable for the pressure to which they may be subjected and are to be made watertight.

Testing

2008 Tunnels are to be hose tested on completion.

Passageways

2009 Where fore and aft underdeck passageways are arranged at the ship's side, the after access thereto is to be by a watertight trunk led to the upper deck. Alternative arrangements to prevent the engine room being flooded in the event of a collision if the passageway doors are left open will be considered.

Section 21

MACHINERY SPACES

Engine Seatings

2101 The main engine seating should, in general, be integral with the double bottom structure; this particularly applies to higher power diesel or turbine installations. The tank top in way of the engine foundation should be substantially increased in thickness.

If the main machinery is supported on built-up seatings, the scantlings of these seatings are to be appropriate to the size of the machinery. Adequate transverse stiffening, in the form of tripping brackets in line with floors, is to be provided. Care must be taken to ensure continuity in strength between the longitudinal girders under the seating and the ship longitudinal girders. (*See* D 920 and D 928).

2102 The plating under the foremost shaft tunnel bearing is to be increased in thickness and is to be scarphed into the heavy plating under the engine bedplate.

Boiler Bearers

2103 Boiler bearers are to be of substantial construction and efficiently supported by transverse brackets and longitudinal girders. (*See* D 910 and D 922).

Clearance between Bulkheads and Boilers

2104 Bulkheads are to be kept well clear of boilers and uptakes, and sufficient space is to be allowed all around boilers for proper access and ventilation.

2105 Decks or flats and the tops of recesses are, in general, to be not less than 1,2 m (4 ft) clear of the boiler top. Uptakes and flat surfaces of boilers are to be not less than 0,450 m (1·48 ft) and the cylindrical shells of boilers not less than 230 mm (9 in) from bunker or hold bulkheads.

Exposed Casings Protecting Machinery Openings

2106 The scantlings of exposed casings protecting machinery openings are to be in accordance with D 1706 or D 1707.

2107 Doors in exposed machinery casings giving direct access to machinery spaces are to be of steel and weather-tight. They are to be permanently attached to the bulkhead by means of hinges and capable of being operated from both sides.

The door sills are not to be less than 600 mm (23·5 in) high if situated on the freeboard deck and not less than 380 mm (15 in) high on the superstructure deck.

In cargo ships of Type B–100 (*see* D 2604) means of access in exposed machinery casings on the freeboard deck is to be in accordance with D 5606.

2108 Cross ties may be required in way of particularly large deck openings.

Protected Casings

2109 Protected machinery casings are to have scantlings not less than:—

Plating in way of cargo spaces, thickness $t = 6{,}5$ mm (0·25 in)

" " " " accommodation spaces, thickness $t = 5$ mm (0·20 in)

Where the spacing of stiffeners exceeds 760 mm (30 in) the plating thickness is to be increased at the rate of 0,25 mm per 76 mm (0·01 in per 3 in) increase.

Stiffeners are to have a section modulus not less than:—

$$\frac{I}{y} = 0{,}008 l s \text{ cm}^3$$

$$\left(\frac{I}{y} = 0 \cdot 004 l s \text{ in}^3\right)$$

where l = length of stiffener in metres (feet),

s = stiffener spacing in mm (inches).

2110 Where casing side stiffeners carry loads from decks above, or where they are in line with pillars below they are to be suitably increased.

2111 Where casing sides act as girder webs supporting tiers of decks above, care must be taken when cutting access openings to ensure that web continuity is maintained. Particular attention should be paid to stiffening where supporting funnel and exhaust uptakes in motor vessels.

Skylights

2112 Engine room skylights, where fitted, are to be substantially constructed and are to be securely connected to the coamings. Gratings over machinery room openings are to be protected by hinged plate covers, which are to be weather-tight if the level of the openings is less than 600 mm (23·5 in) above the top of the hatch coamings required by D 2626. (*See also* F 336).

Means of Escape

2113 In machinery spaces, two means of escape, one of which may be a watertight door, shall be provided from each engine room, shaft tunnel and boiler room. In machinery spaces where no watertight door is available, the two means of escape shall be formed by two sets of steel ladders as widely separated as possible leading to doors in the casing similarly separated and from which access is provided to the lifeboat embarkation deck. In the case of ships of less than 2000 tons gross, this requirement may be dispensed with, due regard being paid to the width and the disposition of the casing.

Communications

2114 Two means of communication are to be fitted between the bridge and the engine room.

Aluminium Alloy

2115 When aluminium alloy is used in the construction of the boundaries of the machinery space or in the casings or pillars, suitable insulation is to be fitted so that the structure remains effective in the presence of intense heat. The extent of the insulation is to be governed by the fire risk on either side of the boundary.

Additional Strengthening in Machinery Space

2116 Additional transverse strengthening is to be provided by means of web frames (*see* D 718) and strong beams, with suitable pillaring or other arrangements.

Machinery Spaces at Aft End of Ship

2117 Where applicable, D 55 is to be used for the construction of machinery spaces in this position.

Cross-references

2118 For passenger ships, *see* F 807, F 812 and F 814. For gutterway and drip trays, *see* D 1927 and D 1928.

Section 22

RUDDERS

Materials

2201 Steel castings are to comply with the requirements of P 5.

2202 Forgings are to comply with the requirements of P 6.

Rudder Stock

2203 The diameter of the rudder stock at and below the lowest bearing is not to be less than given by the following formula. For the minimum diameter of stock above the lowest bearing a in the formula is to be taken equal to zero.

(i) Ahead condition:—

$$d_s = 83{,}3k\left(\sqrt[3]{(V+3)^2\sqrt{A^2S^2+a^2}}\right) \text{ mm} \quad (1)$$

$$\left(d_s = k\left(\sqrt[3]{(V+3)^2\sqrt{A^2S^2+a^2}}\right) \text{ in}\right)$$

where A = rudder area, in m² (ft²),

S = horizontal distance, in metres (feet), from the centreline of the rudder pintles, or axle, to the centre of pressure of the rudder area, but is not to be less than 12 per cent of the breadth of the rudder.

For non-rectangular rudders the minimum value is to be taken as:—

$$\frac{0{,}12 \times \text{Area in m}^2\ (\text{ft}^2)}{\text{Depth on centreline of stock, in metres (feet)}}$$

For rectangular rudders, the centre of pressure may be taken at one-third of the breadth of the rudder from its leading edge.

For the astern condition, *see* (ii),

V = the maximum service speed, in knots, with the ship in the loaded condition,

k = 0,248 for rudders working in a propeller slipstream and 0,235 for rudders situated on the centreline of twin screw ships.

For the astern condition, *see* (ii),

a = a value depending upon the rudder support arrangement and is equal to zero when two or more pintles are fitted.

When one or no pintles are fitted:—

$$a = A_1 \left(\frac{l_1}{1,5} + \frac{l_2}{6}\right) - A_2 \left(l_1 + \frac{l_3}{2}\right) \quad (2)$$

A_1 and A_2 are areas measured, in m^2 (ft^2),

l_1, l_2 and l_3 are measured at the centreline of the rudder stock, in metres (feet).

NOTE:—Where not otherwise shown in Fig. D 22.1 the various values in formula (2) for a are to be set equal to zero.

(ii) Astern condition:—

The rudder stock diameter is to be calculated for the astern condition using the formula given in (i), where:—

V = astern speed, in knots. Unless special service conditions apply, the ship astern speed should be taken as one half the speed ahead,

$k = 0,185$

The centre of pressure of the rudder is to be taken at $0,25\times$ the breadth of the rudder from the aft edge.

Rudder Couplings

2204 Bolts in horizontal couplings are to have a diameter not less than:—

$$d_b = \frac{0{\cdot}65 d_s}{\sqrt{n}} \text{ mm (in)} \quad (1)$$

and the first moment of area of the bolts about the centre of the coupling is not to be less than:—

$$M = \frac{0,71\, n\, d_s\, d_b^2}{1000} \text{ cm}^3 \quad (2)$$

$$(M = 0{\cdot}71\, n\, d_s\, d_b^2 \text{ in}^3)$$

where d_b = bolt diameter, in mm (in),

d_s = rudder stock diameter obtained from 2203, in mm (in),

n = number of bolts but not to be less than six.

The thickness of the coupling flanges is not to be less than d_b mm (in).

2205 Vertical couplings are to have not less than eight securing bolts each having a diameter not less than:—

$$d_b = \frac{0,81 d_s}{\sqrt{n}} \text{ mm (in)} \quad (1)$$

and the first moment of area of the bolts about a vertical axis through the centre of the coupling is not to be less than:—

$$M = \frac{0,43 d_s^3}{1000} \text{ cm}^3 \quad (M = 0{\cdot}43 d_s^3 \text{ in}^3) \quad (2)$$

where d_b, d_s and n are as specified in 2204.

2206 The width of material in coupling flanges outside the boltholes is not to be less than two-thirds of the rule bolt diameter.

2207 Coupling bolts are to be fitted and suitable arrangements are to be made to lock the nuts.

Rudder Pintles

2208 Rudder pintles are to have a diameter not less than:—

$$d_p = 31 + 4,17V\sqrt{A_p} \text{ mm}$$

$$(d_p = 1{\cdot}22 + 0{\cdot}05V\sqrt{A_p} \text{ in})$$

where d_p = pintle diameter (measured outside liner, if fitted),

V = ship speed but is not to be taken as less than 10 knots,

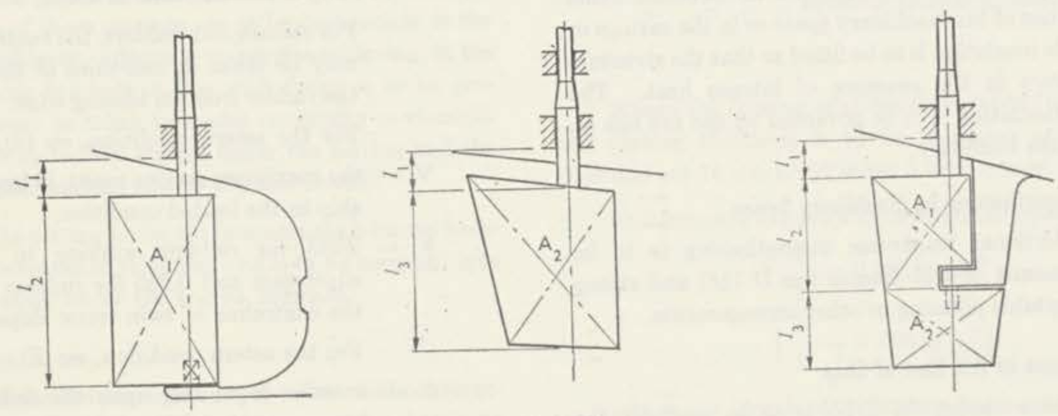


FIG. D 22.1

A = total rudder area, in m² (ft²),

A_P = rudder area supported by the pintle—*see* Fig. D 22.2, but need not be taken greater than A, and for rudders with two or more pintles (except semi-spade rudders as shown) is to be taken as the total area of rudder divided by the number of pintles.

2209 The bearing length of pintles in their gudgeons and housings is, in general, to be 20 per cent greater than the diameter of the pintle obtained from 2208, but for very large pintles may be less, provided that the bearing pressure is not greater than:—

Metal bearings	70 kg/cm² (996 lb/in²)
Lignum vitæ or synthetic bearings... ...	56 kg/cm² (796 lb/in²)

based on the projected area (i.e. length × diameter).

The force acting on the bearing may be taken as

$$F = \frac{A_P (V + 3)^2}{100} \text{ tonnes}$$

$$\left(F = \frac{A_P (V + 3)^2}{1095} \text{ tons} \right)$$

where A_P is as derived from 2208.

In no case is the bearing length to be less than the pintle diameter. The width of material in the gudgeons (measured outside the bushing if fitted) is not to be less than 50 per cent of the rule pintle diameter, but need not normally exceed 125 mm (4·9 in).

2210 Pintles are to have a taper of 1 in 12 on radius.

The bottom pintle on semi-spade type rudders is to be keyed to the rudder or sternframe gudgeon as appropriate.

2211 The pintle clearances with metal bearings should not be less than 1 mm (0·04 in) on the diameter and with synthetic bushes should not be less than 1,5 mm (0·06 in).

2212 Synthetic rudder bearing materials are to be of a type approved by the Society. When this type of lining material is used, an adequate supply of water to the bearing is to be provided.

2213 Where it is proposed to use stainless steel for liners or bearings the chemical composition is to be submitted for approval.

2214 The distance between the lowest rudder stock bearing and the upper pintle should be as short as possible.

2215 Where liners are fitted to pintles they are to be shrunk on or otherwise efficiently secured.

Rudder Plating

2216 Rudder side plating in double plated rudders is to have a thickness not less than:—

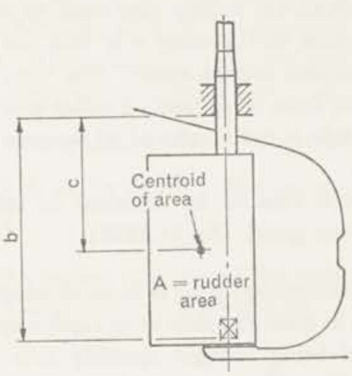
$$t = \frac{b_1 + 610}{1000} \left(4 - \frac{b_1}{s}\right) (1{,}45 + 0{,}1\sqrt{d_s}) \text{ mm}$$

$$\left(t = \frac{b_1 + 24}{1000} \left(4 - \frac{b_1}{s}\right) (1{\cdot}45 + 0{\cdot}504\sqrt{d_s}) \text{ in} \right)$$

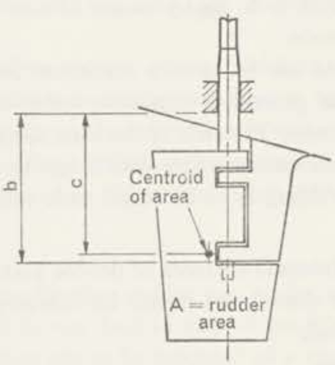
where b_1 = spacing, in mm (in), of the horizontal webs, and is not to exceed 1220 mm (48 in),

s = spacing, in mm (in), of the vertical webs and is not to be taken as less than b_1 in the formula. In general, s is not to exceed $2b_1$ in any panel,

d_s = diameter of rudder stock, in mm (in), required by 2203.



For lower pintle $A_P = \dfrac{A \times c}{b}$



For upper pintle A_P = (A—lower pintle A_P) but not less than 0,35A.

Fig. D 22.2

2217 Vertical and horizontal webs are to have the same thickness as the side plating. *See also* 2219 for vertical webs forming mainpiece.

2218 Nose plates are to have a thickness not less than 25 per cent greater than that required for side plating but need not exceed 22 mm (0·87 in). Top and bottom plates are to have the thickness derived from 2216 with b_1 taken as the maximum rudder width at top or bottom but not less than 900 mm (35·4 in). In way of rudder couplings and heel pintles the plating thickness is to be suitably increased.

Mainpiece

2219 Fabricated mainpieces may be of rectangular or tubular section. The breadth and width of rectangular mainpieces are not to be less than the diameter required by 2203. The thickness of the side plating and vertical webs that form a rectangular mainpiece are not to be less than:—

$$t_m = 8{,}5 + 0{,}56\sqrt{d_s} \text{ mm},$$

$$(t_m = 0{\cdot}335 + 0{\cdot}112\sqrt{d_s} \text{ in}),$$

but need not exceed 25,5 mm (1·00 in).

The increased side plating is to have a minimum fore and aft extent of 20 per cent of the rudder breadth and is to be attached to the two vertical webs forming the mainpiece.

Tubular mainpieces are to have an inside diameter not less than required by 2203, and a thickness not less than t_m mm (in) as given in the previous sub-paragraph, but need not exceed 25,5 mm (1·00 in). When tubular mainpieces are fitted, the rudder side plating in way may be as required by 2216.

General

2220 Connection of rudder side plating to vertical and horizontal webs, where internal access for welding is not practicable, is to be by means of slot welds on to flat bars on the webs.

The slots are to have a minimum length of 75 mm (3 in) and, in general, a minimum width of twice the side plating thickness. The ends of the slots are to be rounded.

The space between the slots is not to exceed 150 mm (6 in) and welding is to be based on a weld factor of 0,44 (0·63).

2221 Internal surfaces of double plate rudders are to be efficiently coated and means for draining the rudder are to be provided.

2222 Where it is intended to fill the rudder with plastic foam, details of the foam are to be submitted.

2223 Suitable arrangements are to be provided to prevent the rudder from lifting.

2224 Where bow rudders are fitted for use when going astern, they are to have a locking device to ensure that the rudder is kept in the central position when the ship is going ahead.

2225 When the weight of the rudder is supported by a carrier bearing attached to the rudder head the structure in way is to be adequately strengthened for that purpose. The plating under all rudder head bearings or rudder carriers is to be increased in thickness.

2226 Adequate hand or access holes are to be arranged in the rudder plating in way of pintles as required, and the rudder is to be reinforced in way of these openings.

Testing

2227 Double plated rudders are to be tested by a head of water of 2,44 m (8 ft) or equivalent.

Cross-reference

2228 For strengthening for navigation in ice, *see* D 24.

Section 23

STEERING GEAR

General

2301 All ships are to be provided with two independent means of moving the rudder. In passenger ships and in cargo ships of 500 tons gross and above, one of the gears is to be operated by power. All gears are to be fitted and tested under working conditions to the satisfaction of the Surveyors.

2302 The power operated main steering gear is to be capable of putting the rudder over from 35 degrees on one side to 35 degrees on the other side with the ship running ahead at maximum service speed. The time taken to put the rudder over from 35 degrees on either side to 30 degrees on the other side is not to exceed 28 seconds at maximum service speed.

The gear is also to be designed in relation to the maximum astern speed. (*See* D 2203.)

2303 The auxiliary gear is to be of adequate strength and sufficient to steer the ship at navigable speed and is to be capable of being brought speedily into action in an emergency.

2304 In cargo ships a power operated auxiliary gear is to be fitted where the Rule diameter of the rudder stock at the tiller, corresponding to a speed of 10 knots, is 250 mm

(10 in) and above. Where main steering gear power units and their connections are fitted in duplicate and the duplicate units acting together satisfy the requirements of 2302, and each power unit separately satisfies the requirements of 2303, an auxiliary gear will not be required.

2305 In passenger ships, the auxiliary gear is to be power operated if the Rule diameter of rudder stock at the tiller exceeds 230 mm (9 in). Where main steering gear power units and their connections are fitted in duplicate and each power unit separately is capable of satisfying the requirements of 2302, an auxiliary gear will not be required.

2306 In passenger ships, where the Rule diameter of the rudder stock at the tiller exceeds 230 mm (9 in), an alternative steering position remote from the main steering position is to be provided. The steering control systems from the main and alternative steering stations are to be arranged so that failure of either system would not result in inability to steer the ship by means of the other system.

Means are to be provided to enable orders to be transmitted from the bridge to the alternative steering station.

2307 The exact position of the rudder, if power operated, shall be indicated at the main steering station.

2308 The after steering wheel and gear in ocean-going ships are to be adequately protected or situated in such a position that protection can be dispensed with.

2309 The steering gear is to be secured to the seating by fitted bolts and suitable chocking arrangements are to be provided.

Tillers and Quadrants

2310 Tillers and quadrants are to be shrunk on or bolted to the rudder stock. The shrinkage allowance is to be between 1/550 and 1/700 of the diameter of the rudder stock in way. When the tiller and quadrant are bolted, or when a shrinkage less than given above is used, a key having an effective sectional area in shear not less than $\dfrac{0{,}25\,d_s^2}{100}$ cm² ($0{\cdot}25\,d_s^2$ in²) is to be fitted. The keyways are to have rounded ends.

2311 The section modulus of the tiller arm just clear of the boss, taken about a vertical axis, is not to be less than:—

For a single arm tiller $$\frac{I}{y} = \frac{0{,}15 d_s^3\,(a-b)}{1000a}\ \text{cm}^3$$

$$\left(\frac{I}{y} = \frac{0{\cdot}15 d_s^3\,(a-b)}{a}\ \text{in}^3\right)$$

Where d_s = diameter of rudder stock, in mm (in), at the tiller head, as obtained from D 2203,

a = distance from the point of application of the load on the tiller to the centre of the rudder stock, in mm (in),

b = distance between the section of the tiller arm under consideration and the centre of the rudder stock, in mm (in).

NOTE:—a and b are to be measured with zero rudder angle.

Where more than one arm is fitted the combined modulus of the arms is not to be less than as required above.

For solid tillers the breadth to depth ratio is not to be more than 2.

2312 The depth of the boss is not to be less than the diameter of the rudder stock d_s. The thickness of the boss in way of the tiller is not to be less than $0{,}4d_s$.

2313 At the point of application of the load the tiller arm can have a section modulus of 40 per cent of that required by 2311 for the section just clear of the boss.

The modulus of the arm may be tapered gradually to this point.

2314 The diameter of bolts in bolted tillers or quadrants is not to be less than:—

$$d_b = \frac{0{,}60 d_s}{\sqrt{n}}\ \text{mm (in)}$$

Where d_s is as defined in 2311,

n = total number of bolts in the coupling.

Locking or Brake Gear

2315 An efficient locking or brake arrangement is to be fitted to all gears to keep the rudder steady when necessary.

In bow rudders where a vertical locking pin is operated from the deck above, positive means are to be provided to ensure that the pin can be lowered only when the rudder is exactly central. In addition, an indicator is to be fitted at the deck to show when the rudder is exactly central.

Rudder Stops

2316 Stops for the rudder are to be provided and strongly secured to the deck in way of the tiller. Stops on the steering engine are to be arranged at a smaller angle of helm than those for the rudder.

Cross-reference

2317 For strengthening for navigation in ice, *see* D 24.

Section 24

STRENGTHENING FOR NAVIGATION IN ICE

Symbols

2401 L = length of ship, in metres (feet),

L_1 = length of ship, in metres (feet), but need not be taken as greater than 215 m (705 ft),

B = moulded breadth, in metres (feet),

s = frame spacing, in mm (in),

s_b = basic frame spacing, in mm (in), i.e. (i) aft of 0,2L from fore perpendicular to the after peak bulkhead:—

$$\frac{L_1}{0,6} + 510 \text{ mm}$$

$$\left(\frac{L_1}{50} + 20 \text{ in}\right)$$

(ii) forward of 0,2L from fore perpendicular to the fore peak bulkhead:— as required by D 705, but is not to exceed the spacing required by (i) above.

(iii) in peaks and cruiser sterns:— as required by D 706.

t_b = basic ice shell plating thickness, =

$$\left(5 + \frac{L}{13,65}\right)\sqrt{\frac{s}{s_b}} \text{ mm}$$

$$\left(\left(0,20 + \frac{L}{1140}\right)\sqrt{\frac{s}{s_b}} \text{ in}\right)$$

s.h.p. = maximum designed shaft horse power.

2402 The vertical extent of ice strengthening is related to Light and Load waterlines which are to be determined as follows:—

Light waterline: is the lowest waterline, taking account of trim, at any point along the length of the ship corresponding to either of the following conditions:—

(*a*) The lightest load condition in which the ship may be expected to be at sea in ice conditions,

(*b*) The ballast condition.

Load waterline: is that corresponding to the winter load line. (For ships trading in the Baltic at the summer load line, the ice strengthening is to be based on this load line. In these cases a suitable notation will be made in the Register Book.)

The position of maximum breadth on the winter load waterline is to be indicated on the plans.

FRAMING

Class 1*

2403 The frame spacing is not, in general, to exceed 610 mm (24 in) between the forward perpendicular and ·25L forward of amidships and 800 mm (31·5 in) over the remainder of the length to the after peak bulkhead.

2404 Intermediate frames are to be fitted over the full length of the ship. The strength of these frames is to be the same as that of the adjacent rule main or 'tween deck frames.

In way of deep tanks the section modulus of intermediate frames may be that of the main frames before the increase required by D 720 is applied.

In the panting region clear of deep tanks the intermediate frames may have a section modulus as derived from D 707 (2) but ignoring the factor f.

The intermediate frames are to extend from the upper deck, or from the second deck provided this is at least 750 mm (29·5 in) above the load waterline, to below the level of the top of floors or to a point just above the tank top where this runs horizontally to the ship's side, and need not be connected at their ends. Where the second deck is above the load waterline but less than 750 mm (29·5 in) above, the intermediate frames may terminate at a stringer situated not less than 1,2 m (4 ft) above the load waterline.

In the fore and aft peaks the main and intermediate frames are to have the same modulus as an amidship frame determined from D 707 (1) with a frame spacing equal to $\frac{L_1}{0,6} + 510$ mm $\left(\frac{L_1}{50} + 20 \text{ in}\right)$, or a modulus equal to twice that of the normal peak frames whichever is the greater.

Where the frames terminate at the 2nd deck, and long or broad hatchways are fitted in this deck, the plating in way of the hatchways is to be suitably strengthened by fitting web frames or strong beams to give adequate support to the framing.

Class 1

2405 Intermediate frames are to be fitted over the full length of the ship. The strength of these frames is to be the same as that of the adjacent Rule main or 'tween deck frames, unless stringers are fitted in accordance with 2429 when the intermediate frames may be 75 per cent of the adjacent Rule frames.

In way of deep tanks the section modulus of intermediate frames may be that of the main frames before the increase required by D 720 is applied.

In the panting region clear of deep tanks the intermediate frames may have a section modulus as derived from D 707 (2) but ignoring the factor f.

The intermediate frames are to extend from 915 mm (36 in) below the light waterline to 750 mm (29·5 in) above the load waterline. They are to be connected at their ends to the adjacent frames by a horizontal member having the same scantlings as these frames, or equivalent arrangements are to be provided. Alternatively, they are to be carried down to within 255 mm (10 in) of the margin plate or, where the ship has no double bottom, to a point below the top of the floors. If the frames are so extended they need not be attached at the lower end.

In the fore and aft peaks the main and intermediate frames are to have the same modulus as an amidship frame determined from D 707 (1) with a frame spacing equal to $\frac{L_1}{0,6} + 510$ mm $\left(\frac{L_1}{50} + 20 \text{ in}\right)$, or a modulus equal to twice that of the normal peak frames, whichever is the greater.

Class 2

2406 Intermediate frames are to be as required by 2405 except that they need only be fitted in the region from the forward perpendicular aft for a length equal to the distance from the forward perpendicular to the point where the load waterline reaches its greatest breadth plus 10 per cent. of that distance.

Class 3

2407 For the longitudinal extent given in 2406 intermediate frames are to be fitted abaft the forward perpendicular. They are to extend from 915 mm (36 in) below the light waterline to 750 mm (29·5 in) above the load waterline, and need not be connected at their ends.

The intermediate frames forward of the collision bulkhead should have a modulus equal to 50 per cent of the Rule peak frames, and those aft of the collision bulkhead should have a modulus equal to 80 per cent of the adjacent Rule frames unless stringers are fitted in accordance with 2431. In this case the intermediate frames aft of the collision bulkhead should have a modulus equal to 75 per cent of the Rule peak frames, but in 'tween decks need not exceed the adjacent frame.

General

2408 For classes 1*, 1 and 2, frames are not to be scalloped, except at the seams in the shell plating, over the area defined in 2410.

2409 Attention is to be paid to the minimum thickness of frames and other stiffening members. In general, this should not be less than one-half that of the attached hull plating.

Where stringers are not fitted, brackets are to be arranged to prevent the frames from tripping.

SHELL PLATING

Class 1*

2410 From the forward perpendicular aft for a length equal to the distance from the forward perpendicular to the point where the load waterline reaches its greatest breadth plus 10 per cent of that distance, and extending vertically from 610 mm (24 in) below the light waterline to 750 mm (29·5 in) above the load waterline, the thickness of the shell plating is not to be less than $1,8\, t_b$ mm (in).

2411 From this position to 0,25L aft of amidships and over the same vertical extent, the thickness of shell plating is not to be less than $1,4 t_b$ mm (in).

If the parallel middle portion on the load waterline extends further aft than 0,25L aft of amidships, the shell plating over this parallel middle portion is also not to be less than $1,4\, t_b$ mm (in).

2412 For the remainder of the length and over the same vertical extent, the thickness of shell plating is not to be less than $1,25\, t_b$ mm (in).

2413 The side and bottom shell plating below this belt from the stem to a position five frame spaces abaft the point where the bow profile departs from the level keel line is not to be less than $1,8\, t_b$ mm (in).

2414 The increased thickness need not exceed 32 mm (1·25 in), but is not to be less than 14 mm (0·55 in). Changes in thickness are to take place gradually.

2415 When the s.h.p. exceeds 2,26 ($L \times B$), or in British units 0·21 ($L \times B$), the shell plating for the longitudinal extent given in 2410 shall be increased by a further 1 mm (0·04 in) for each 500 s.h.p. excess over the above figure. (The s.h.p. is to be indicated on the plan on which the shell plating is approved).

Class 1

2416 For the longitudinal and vertical extent given in 2410 the thickness of the shell plating is not to be less than $1,5 t_b$ mm (in).

2417 For the remainder of the length and over the same vertical extent the thickness of shell plating is not to be less than $1,25 t_b$ mm (in).

2418 The increased thickness need not exceed 25,5 mm (1·00 in), but is not to be less than 12,5 mm (0·50 in). Changes in thickness are to take place gradually.

Class 2

2419 For the longitudinal and vertical extent given in 2410 the thickness of the shell plating is not to be less than $1,5 t_b$ mm (in).

2420 For the remainder of the length and over the same vertical extent the thickness of shell plating is not to be less than $1{,}15t_b$ mm (in).

2421 The increased thickness need not exceed 25,5 mm (1·00 in), but is not to be less than 12,5 mm (0·50 in). Changes in thickness are to take place gradually.

Class 3

2422 For the vertical extent given in 2410 and from the forward perpendicular to the point where the load waterline reaches its greatest breadth the thickness of the shell plating is not to be less than $1{,}25\ t_b$ mm (in).

2423 For the remainder of the length, the thickness is to be normal Rule.

2424 The increased thickness need not exceed 25,5 mm (1·00 in), but is not to be less than 12,5 mm (0·50 in). Changes in thickness are to take place gradually.

STRINGERS

Class 1*

2425 Forward of the collision bulkhead the tiers of beams and stringers required by D 11 are to be spaced not more than 1,3 m (4·25 ft) apart.

2426 Abaft the collision bulkhead the stringer next below the load waterline is to be extended over the full length of the ship, unless a deck is situated not more than 1,2 m (4 ft) below the load waterline, and the main and intermediate frames are to be attached thereto.

The stringers immediately above and below this stringer are also to be extended over the full length of the ship, but may be intercostal and of the same scantlings as the frames in way.

2427 Where the light waterline lies well above the margin a stringer may be required in the vicinity of the light waterline and over the full length of the ship.

2428 In single deck ships a stringer is to be arranged in the vicinity of the load waterline, over the full length of the ship.

Class 1 and Class 2

2429 The following requirements apply only when the intermediate frames are made 75 per cent of the adjacent Rule main or 'tween deck frames. *See* 2405.

Abaft the collision bulkhead stringers of the scantlings given in D 11 are to be fitted 2 m (6·56 ft) apart for the longitudinal extent given in 2410.

2430 The stringer next below the load waterline is to be extended over the full length of the ship unless a deck is situated not more than 600 mm (23·5 in) below the load waterline, for Ice Class I only.

Class 3

2431 When the intermediate frames are made 75 per cent of the Rule peak frames (*see* 2407), stringers of the scantlings given in D 11 are to be fitted 2 m (6·56 ft) apart abaft the collision bulkhead for the longitudinal extent given in 2410.

General

2432 Attention is to be paid to the minimum thickness of stringers. In general, this should be not less than one-half that of the attached hull plating.

RUDDER & STEERING ARRANGEMENTS

2433 The diameters of the rudder head and pintles are to be increased above that required by D 22 by:—

Class 1* — 30 per cent,
Class 1 — 25 per cent,
Class 2 — 12,5 per cent,
Class 3 — 7,5 per cent.

2434 The side plating and webs of double plate rudders are to be increased above that required by D 22 by:—

Class 1* — 50 per cent,
Class 1 — 50 per cent,
Class 2 — 25 per cent,
Class 3 — 10 per cent.

2435 The gudgeons, remaining rudder items and couplings are to be based on the increased rudder head or pintle and the steering gear is to be suitably protected against, or designed to withstand, the increased loading.

In welded double plate rudders, the horizontal and vertical webs are not to be welded direct to the side plates, but are to be attached to flat bars or equivalent arrangements made to avoid hard points.

2436 The rudder head is to be protected by an ice knife, a suitable stern, or other equivalent arrangements—Ice Classes 1* and 1 only.

STERNFRAME

2437 The strength of the rudder horn, rudder post and solepiece and the diameter of the rudder axle (if fitted) are to be increased above the rule requirements by:—

Class 1* — 30 per cent,
Class 1 — 25 per cent,
Class 2 — 15 per cent,
Class 3 — 7,5 per cent.

STEM

Class 1*

2438 The bow should be of a form specially designed for navigation in ice.

A solid stem of forged, rolled or cast steel is to be fitted up to 750 mm (29·5 in) above the load waterline.

General

2439 The sectional area of a solid stem bar is to be greater than rule requirements by:—

Class 1* — 30 per cent,
Class 1 — 25 per cent,
Class 2 — 15 per cent,
Class 3 — 10 per cent.

The connections of the shell plating to the stem bar are to be flush.

2440 Where a plate stem is fitted, the thickness of the plates below a position 750 mm (29·5 in) above the load waterline is not to be less than:—

Class 1* — 1,8 t_b
Class 1 — 1,65 t_b
Class 2 — 1,65 t_b
Class 3 — 1,5 t_b

but need not exceed 25,5 mm (1·00 in).

t_b is to be determined using $s = \frac{L_1}{0{,}6} + 510$ mm

$$\left(\frac{L_1}{50} + 20 \text{ in}\right)$$

The thickness may be tapered to that of the normal plate stem (*see* D 1205) at the upper deck. Plates which require to be furnaced are to have these thicknesses when finished.

2441 Below the load waterline, plate stems should be reinforced by a centreline web—Ice Classes 1* and 1 only—and by horizontal webs. The horizontal webs are to be spaced not more than 700 mm (27·5 in) for Class 1* and 915 mm (36 in) for other classes.

GENERAL

Cross-reference

2442 For machinery requirements, *see* H 5.

Section 25

DECK LOADING

Permissible Cargo Loading on Decks and Hatch Covers having minimum Rule Scantlings

Weather Decks

2501 That equivalent to a 1,2 m (4 ft) head with a stowage rate of 1,39 m^3/tonne (50 ft^3/ton) i.e. 0,87 tonne/m^2 (0·08 ton/ft^2).

Cargo Decks

2502 That equivalent to a head equal to the 'tween deck height (h metres (feet)) with a stowage rate of 1,39 m^3/tonne (50 ft^3/ton) i.e. 0,72h tonne/m^2 (0·02h ton/ft^2). (*See also* 2504).

Hatch Covers

2503 For hatch covers fitted on weather decks in positions 1 and 2 (*see* D 2605), the maximum cargo load is that equivalent to a head of 1,5 m (5 ft) and 1,2 m (4 ft) respectively, with a stowage rate of 1,39 m^3/tonne (50 ft^3/ton), unless the supporting deck girders and pillars are increased in size, in which case, *see* 2509 and 2510.

Lower Decks forming crown of Deep or Tunnel Tanks

2504 That equivalent to the greater of the following:-

(a) A head equal to the 'tween deck height with a stowage rate of 1,39 m^3/tonne (50 ft^3/ton),

(b) A head equal to one half the height of the air pipe above the tank crown with a stowage rate of 0,975 m^3/tonne (35 ft^3/ton).

Inner Bottom

2505 For ships having the class 100A1 the loading on the tank top may be that equivalent to a head of 1,4d with a stowage rate of 1,39 m^3/tonne (50 ft^3/ton). d is the load draught, in metres (feet).

For ships having Heavy Cargo or Ore Cargo notations the inner bottom may be suitable for increased loads—*see* D 609 and D 610.

Specified Cargo Loading on Decks and Hatch Covers in excess of that given in 2501 to 2504

2506 If the actual loading is in excess of the nominal Rule loading, then the appropriate h values, with the exceptions given in 2507, 2508, 2509 and 2510, are to be increased in direct proportion.

2507 For weather deck hatch side coamings, hatch end beams, girders and pillars, the head h to be used is 1,39 p m (50 p ft), plus an allowance for weather as follows:—

(i) when the basic h as obtained from D 6 or D 8 is 1,2 m (4 ft) or less —— nil.

(ii) when h obtained from D 6 or D 8 is 1,5 m (5 ft) —— 0,3 m (1 ft).
(Intermediate values are to be in proportion.)

p = actual deck loading in tonne/m^2 (ton/ft^2).

2508 For deck longitudinals and beams, the scantlings are to be obtained from D 604 and D 809, using the head obtained from 2506 for cargo decks and 2507 for weather decks. The modulus of weather deck longitudinals or beams is not to be less than that obtained from D 602 and D 806.

2509 Hatch covers in position 1 need not be increased where the head obtained from 2506 (i.e. without any addition for weather) is 2,44 m (8 ft) or less; when it exceeds 2,44 m (8 ft) the scantlings are to be increased in direct proportion.

2510 Hatch covers in position 2 need not be increased where the head obtained from 2506 (i.e. without any addition for weather) is 1,8 m (5·9 ft) or less; when it exceeds 1,8 m (5·9 ft) the scantlings are to be increased in direct proportion.

2511 Where heavy loads are to be carried, the side framing in way may require to be strengthened.

Concentrated Loads

2512 Where provision is required for concentrated loads, then scantlings and arrangements will be considered.

See D 418 for fork lift trucks.

Hanging Cargoes

2513 *See* D 603, D 605, D 807 and D 810.

Fruit or similar Light Cargoes

2514 Where the deck is designed for the carriage of fruit or similar light cargoes only, the head used for the calculations can be reduced in a similar manner to that given in 2506 but is not to be taken as less than 1,2 m (4 ft).

Section 26

HATCHWAYS AND DECK OPENINGS

Definitions

2601 L = length of ship, in metres (feet).

h = head, in metres (feet), and is to be taken as follows:—

For position 1, h = 2,45 m (8 ft)

For position 2, h = 1,8 m (5·9 ft)

For definition of positions 1 and 2—*see* 2605.

In 'tween decks, h = 'tween deck height, in metres (feet), measured vertically on the centreline of the ship from deck to deck, i.e., ignoring hatch coamings.

The above heads apply in conjunction with a stowage rate of 1,39 m^3/tonne (50 ft^3/ton).

For specified loading on hatch covers where h is in excess of the above, *see* D 25.

The following definitions apply to webs or stiffeners with attached plating, or portable beams:—

l_0 = unsupported span, in metres (feet), measured as shown in Fig. D 26.1,

l_1 = proportion of the span, in metres (feet), measured as shown in Fig. D 26.1. The depth and face area over the remainder of the span is assumed to be constant.

s = spacing, in mm (inches),

d = overall depth at the supports, measured as shown in Fig. D 26.1, but is not to be less than 150 mm (6 in)—*see also* definition of I_1.

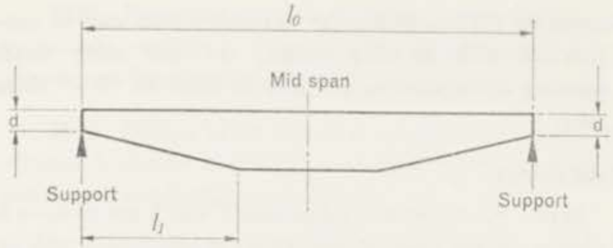


FIG. D 26.1—DIAGRAMMATIC PROFILE OF WEB OR STIFFENER OR PORTABLE BEAM

$$\alpha = \frac{l_1}{l_0}$$

$\left(\frac{I}{y}\right)_0$ = Section modulus, in cm^3 (in^3), at midspan.

$\left(\frac{I}{y}\right)_1$ = Section modulus, in cm^3 (in^3), at supports.

$$\gamma = \frac{\left(\frac{I}{y}\right)_1}{\left(\frac{I}{y}\right)_0}$$

$$K = 1 + \frac{3{,}2\alpha - \gamma - 0{,}8}{7\gamma + 0{,}4}$$

but not less than 1,0. — To be specially considered when discontinuities in area of face material occur.

I_0 = moment of inertia, in cm^4 (in^4), at midspan.

I_1 = moment of inertia, in cm^4 (in^4), at supports, and is not to be less than 0,05 I_0.

$$\beta = \frac{I_1}{I_0}$$

$$C = 1 + \frac{8\,\alpha^3\,(1-\beta)}{0{,}2 + 3\sqrt{\beta}}$$

To be specially considered when discontinuities in area of face material occur.

Application

2602 The scantlings given in this section apply basically to rectangular covers with the stiffening members arranged primarily in one direction, and carrying a uniformly distributed load. Where covers have members arranged in a grillage formation, and/or point loads are applied, the scantlings of the covers will be specially considered.

Other Materials

2603 The scantlings given in this section are applicable to mild steel. Where other materials, such as aluminium are to be used, equivalent scantlings are to be provided.

WEATHER DECK HATCHWAYS

2604 For the purposes of this Section, four basic types of ship are defined:—

B—100 cargo ships with tanker freeboard,

B—60 cargo ships with intermediate freeboard,

B cargo ships with "Type B" freeboard,

B+ cargo ships with increased freeboard.

Position of Hatchways

2605 Position 1 hatchways on exposed freeboard and raised quarter decks, and exposed superstructure decks within the forward 0,25L.

Position 2 hatchways on exposed superstructure decks abaft the forward 0,25L.

Steel Covers Fitted with Direct Securing Arrangements for "B—100", "B—60" or "B" Type Ships

2606 These are plated covers stiffened by webs or stiffeners, weathertightness being obtained by gaskets and clamping devices.

The section modulus and moment of inertia of the webs or stiffeners are to satisfy the following formulæ respectively:—

(i) $$\frac{hsl_0^2 K}{107{,}5\left(\frac{I}{y}\right)_0} \leqslant 1 \qquad \left(\frac{hsl_0^2 K}{2450\left(\frac{I}{y}\right)_0} \leqslant 1 \text{ British}\right)$$

(ii) $$\frac{hsl_0^3 C}{63{,}7\, I_0} \leqslant 1 \qquad \left(\frac{hsl_0^3 C}{12\,100\, I_0} \leqslant 1 \text{ British}\right)$$

(iii) The thickness of plating is not to be less than:—

$t = \frac{s}{100}$ mm (in) or 6 mm (0·24 in), whichever is the greater.

Where h exceeds 3,5 m (11·5 ft) the above thicknesses are to be increased by the factor

$$\sqrt[3]{\frac{h}{3{,}5}} \qquad \left(\sqrt[3]{\frac{h}{11{\cdot}5}} \text{ British}\right).$$

2607 Securing cleats and cross joint wedges, together with suitable jointing material, are to be fitted to secure the weathertightness of the covers to the satisfaction of the Surveyors. The arrangements shall ensure that the tightness can be maintained in any sea conditions, and for this purpose tests for tightness shall be required at the initial survey, and

may be required at periodic surveys and at annual inspections or at more frequent intervals.

The spacing of securing cleats on hatches is to be as follows:—

Hatch sides—cleats are to be spaced about 2 m (6·6 ft) apart with generally a minimum of 2 cleats per panel. Where hydraulic or mechanical means of securing are employed one securing device per panel will be considered assuming arrangements are provided for inter-locking the panels.

Hatch ends—cleats are to be spaced about 2 m (6·6 ft) apart with one arranged adjacent to each corner.

Cross-joint wedges to be spaced about 1,5 m (4·9 ft) apart. Alternatively, where positive securing devices are arranged on the lower side of the joint to ensure continuing compression of the joint, these can be accepted about 3 m (9·8 ft) apart.

Steel hatch covers with special sealing arrangements or insulated covers will be specially considered.

2608 Where it is proposed to omit coamings on weather decks, the strength and closing arrangements of the hatch covers will be specially considered.

2609 Where hatch covers are fitted to holds used as tanks the strength, stiffness, sealing and securing arrangements will be specially considered.

Steel Pontoon Covers—For "B" Type Ships Only

2610 These are plated covers having interior webs and stiffeners, extending for the full width of the hatchway and about one quarter of the length, and not fitted with direct securing arrangements.

The section modulus and moment of inertia of the webs or stiffeners are to satisfy the following formulæ respectively:—

(i) $$\frac{hs l_o^2 K}{91{,}3\left(\frac{I}{y}\right)_o} \leqslant 1 \qquad \left(\frac{hs l_o^2 K}{2080\left(\frac{I}{y}\right)_o} \leqslant 1 \text{ British}\right)$$

(ii) $$\frac{hs l_o^3 C}{50\, I_o} \leqslant 1 \qquad \left(\frac{hs l_o^3 C}{9500\, I_o} \leqslant 1 \text{ British}\right)$$

(iii) The plating thickness is to be as required by 2606 (iii).

2611 The requirements of 2621 to 2625 are to be complied with.

Paragraphs 2612 to 2625 refer to hatch covers used in conjunction with portable beams, and not using direct securing arrangements, and may be fitted on "B+" ships only.

Wood Covers

2612 Wood covers at positions 1 and 2 are to have a thickness not less than 60 mm ($2\frac{3}{8}$ in) in association with an unsupported span of 1,5 m (4·9 ft) and 82 mm ($3\frac{1}{4}$ in) with 2 m (6·56 ft); the thicknesses for intermediate spans are to be in proportion.

2613 The ends of all wood hatch covers are to be protected by encircling galvanised steel bands about 65 mm (2·5 in) wide and 3 mm ($\frac{1}{8}$ in) thick, efficiently secured.

Portable Steel Covers

2614 The section modulus and moment of inertia of stiffeners is to be in accordance with 2606. The thickness of plating is not to be less than:—

$$t = \frac{s}{100} \text{ mm (in) or } 3{,}5 \text{ mm } (0\cdot 14 \text{ in})$$

whichever is the greater.

Hatch Rests

2615 Hatch rests are to provide at least 65 mm (2·5 in) bearing surface and are to be bevelled if required to suit the slope of the hatches.

Portable Hatch Beams

2616 The section modulus and moment of inertia of portable web plate beams stiffened at their upper and lower edges by continuous flat bars are to satisfy the following formulæ respectively:—

(i) $$\frac{hs l_o^2 K}{91{,}3\left(\frac{I}{y}\right)_o} \leqslant 1 \qquad \left(\frac{hs l_o^2 K}{2080\left(\frac{I}{y}\right)_o} \leqslant 1 \text{ British}\right)$$

(ii) $$\frac{hs l_o^3 C}{50\, I_o} \leqslant 1 \qquad \left(\frac{hs l_o^3 C}{9500\, I_o} \leqslant 1 \text{ British}\right)$$

2617 The ends of web plates are to be doubled or inserts fitted at least 180 mm (7 in) wide.

2618 At beams which carry the ends of wood or steel hatch covers a vertical 50 mm (2 in) flat is to be arranged on the upper face plate and the bearing surface for hatch covers is not to be less than 65 mm (2·5 in).

2619 Portable beams are to be supported at their ends by carriers, sockets or other suitable arrangements, having a minimum bearing surface of 75 mm (3 in).

2620 Sliding hatch beams are to be provided with an efficient device for locking them in their correct fore and aft positions when hatchway is closed.

Tarpaulins and Securing Arrangements

2621 At least two layers of tarpaulin in good condition shall be provided for each hatchway in positions 1 or 2.

2622 Tarpaulins are to be free from jute, thoroughly waterproofed and of ample strength. The minimum weight of the material before treatment is to be 0,65 kg/m^2 (19 oz/yd^2) if the material is to be tarred, 0,60 kg/m^2 (18 oz/yd^2) if to be chemically dressed, or 0,55 kg/m^2 (16 oz/yd^2) if to be dressed with black oil.

A certificate to the above effect is to be supplied by the makers of the tarpaulins.

Special consideration will be given when covers of synthetic material are proposed in lieu of tarpaulins.

2623 Cleats are to be of an approved pattern at least 65 mm (2·5 in) wide, with edges so rounded as to minimise the cutting of the wedges, and shall be spaced not more than 600 mm (23·5 in) from centre to centre; the cleats along each side or end are to be arranged not more than 150 mm (6 in) from the hatch corners.

The thickness should not be less than 9,5 mm ($\frac{3}{8}$ in) for angle cleats, and 11 mm ($\frac{7}{16}$ in) for smithed cleats which should be stiffened by pressing out the centre to form a web extending to the bottom of the palm. Drop forgings should be of equivalent strength. Cleats should be so set as to fit the taper of the wedges.

2624 Battens and wedges shall be efficient and in good condition. Wedges are to be of tough wood, generally not less than 200 mm (8 in) in length and 50 mm (2 in) in width. They should have a taper of not more than 1 in 6 and should not be less than 13 mm (0·5 in) at the point.

2625 For all hatchways in positions 1 and 2, steel bars or other equivalent means shall be provided in order efficiently and independently to secure each section of hatch covers after the tarpaulins are battened down.

Hatch covers of more than 1,5 m (4·9 ft) in length are to be secured by at least two such securing appliances. Where hatchway covers extend over intermediate supports, steel bars or their equivalent are to be fitted at each end of each section of covers. At all other hatchways in exposed positions on weather decks ring bolts or other fittings for lashings are to be provided.

Hatchway Coamings

2626 The height of coamings above the upper surface of the deck, measured above sheathing if fitted, for hatchways closed by portable covers secured weathertight by tarpaulins and battening devices is not to be less than:—

Position 1 600 mm (23·5 in)

Position 2 450 mm (17·5 in)

The height of coamings of hatchways situated in positions 1 or 2 and closed by steel covers fitted with direct securing arrangements are to be as specified above, but may be reduced or the coamings omitted entirely if the safety of the ship is not impaired in any sea conditions.

In the case of flush hatch covers or those having coamings less than stated in this paragraph the scantlings and securing arrangements will be specially considered.

2627 Hatchways on other decks and in positions not detailed in 2626 are to be suitably framed.

Construction of Weather Deck Coamings

2628 The thickness of hatch coamings is not to be less than 11 mm (0·43 in).

2629 Coamings 600 mm (23·5 in) or more in height are to be stiffened on their upper edges by a horizontal bulb flat or equivalent not less than 180 mm (7 in) in depth. Additional support is to be afforded by fitting brackets or stays from the bulb flat to the deck at intervals of not more than 3 m (9·84 ft).

Coamings less than 600 mm (23·5 in) in height are to be stiffened on their upper edges by a substantial moulding.

2630 The scantlings and arrangements of coamings more than 900 mm (35·5 in) in height and of coamings acting as girders will be specially considered.

2631 Side coamings of all hatchways are to extend at least to the lower edge of the deck beams which are to be effectively attached to the coamings as required by Table D 32.1.

2632 Extension brackets or rails arranged approximately in line with the hatch side coamings and intended for stowage of steel covers are not to be welded to a deckhouse, masthouse, or to each other, unless they form part of the longitudinal strength members.

2633 For details of arrangement of coamings at hatch corners, *see* D 419.

HATCHWAYS IN CARGO OR ACCOMMODATION SPACES

2634 In cargo spaces, steel hatch covers (including pontoon covers) and portable hatch beams are to have scantlings and arrangements as required by 2606, but modified as follows:—

(a) The section modulus may be 6 per cent less than given by 2606 (i).

(b) The inertia requirements may be 20 per cent less than given by 2606 (ii).

2635 In accommodation spaces, the 'tween deck height (h) is to be taken as 1,8 m (5·9 ft).

2636 Wood covers are to have a thickness not less than 60 mm ($2\frac{3}{8}$ in) in association with an unsupported span of 1,5 m (4·9 ft) and 82 mm ($3\frac{1}{4}$ in) with 2 m (6·56 ft); the thicknesses for intermediate spans are to be in proportion.

When the 'tween deck height (h) exceeds 2,6 m (8·5 ft) the thickness of the covers is to be increased at the rate of 16,5 per cent per metre (5 per cent per foot) excess in 'tween deck height.

For details of wood covers, *see* 2613.

Fork Lift Trucks

2637 Where fork lift trucks are to be used the thickness of the hatch cover plating is to be in accordance with D 418 and the modulus of the stiffeners is to be not less than:—

$$\frac{I}{y} = F_1 T l + \frac{F_2 h l^2 s}{600} \text{ cm}^3 \text{ (in}^3\text{)}$$

but neither is to be less than required by 2634. F_1 and F_2 are coefficients obtained from Table D 26.1, and T = total weight of truck and its load in tonnes (tons).

Where unusual arrangements of hatch cover stiffening are proposed, the scantlings of stiffeners may be approved on the basis of a grillage type calculation.

Tank Hatch Covers in 'Tween Decks

2638 The scantlings of steel tank hatch covers situated in 'tween decks are to be determined as for cargo deck hatch covers but the scantlings must in no case be less than would be required by D 19 for a deep tank bulkhead.

The maximum spacing of cleats and cross-joint wedges is to be 600 mm (23·5 in), but cleats are to be arranged as close as practicable to the corners.

GENERAL

Bunker, Access and Trimming Hatchways

2639 The construction and the closing and securing arrangements of bunker, access and trimming hatchways are to comply with the requirements of 2601 to 2633 so far as applicable.

TABLE D 26.1

Distance between load-bearing wheels / Stiffener span	F_1	F_2
0,1	11,96 (0·226)	2,32 (0·102)
0,2	10,69 (0·202)	1,89 (0·083)
0,3	9,58 (0·181)	1,55 (0·068)
0,4	8,46 (0·160)	1,28 (0·056)
0,5	7,46 (0·141)	1,07 (0·047)
0,6	6,51 (0·123)	0,91 (0·040)
0,7	5,55 (0·105)	0,73 (0·032)
0,8	4,23 (0·080)	0,36 (0·016)
0,9	2,38 (0·045)	0,11 (0·005)

Manholes and Flush Scuttles

2640 Manholes and flush scuttles fitted in positions 1 or 2 or within superstructures other than enclosed superstructures, are to be closed by substantial covers capable of being made watertight. Unless secured by closely spaced bolts, the covers shall be permanently attached.

Trunked Hatchways

2641 When hatchways are trunked through one or more 'tween decks, and hatchway beams and covers are dispensed with at the intermediate decks, the hatchway beams, coamings and covers immediately below the trunk are to be adequately strengthened; plans are to be submitted for approval.

Means of Escape

2642 In and from all crew and passenger spaces and spaces in which crew are normally employed, other than machinery spaces, stairways and ladders are to be arranged so as to provide ready means of escape to the lifeboat embarkation deck. (For means of escape from machinery spaces, *see* D 2113.)

Companionways

2643 Companionways on exposed decks are to be of steel effectively secured to the deck. The height, measured above sheathing if fitted, of the doorway sills in companionways is not to be less than 600 mm (23·5 in) in position 1 and 380 mm (15 in) in position 2, *see* 2605.

2644 The doors in positions 1 and 2—*see* 2605—are to be made of steel or equivalent material, and are to be secured weathertight by gaskets and clamping devices or equivalent means.

Elsewhere, doors may be of hardwood not less than 50 mm (2 in) in thickness.

All doors are to be capable of being operated and secured from both sides.

Cross-reference

2645 For welding requirements, *see* Table D 32.1.

Section 27

MASTS AND RIGGING

2701 The scantlings of steel masts and derrick posts intended to support derrick booms of 15 tonnes (tons) S.W.L. and under are to be determined from the greatest stresses expected to arise when the cargo gear is correctly used. The scantlings of masts and derrick posts supporting one or more derrick booms with a S.W.L. exceeding 15 tonnes (tons) and those of bipod or other special designs including stayed masts where the stays are attached to the outer end of crosstrees will be considered in accordance with the Society's Code of Practice for the Construction and Survey of Ship's Cargo Handling Gear.

Mild steel used for masts, derrick posts, etc., and their associated crosstrees and brackets is to be of D quality if the thickness exceeds 20,5 mm (0·80 in).

2702 A stayed mast or derrick post is one that is supported by one or more stays. A "stay" includes shrouds, forestays, backstays, etc.

Calculations—General

2703 The derrick or derricks are to be assumed to be initially at an angle of 30° to the horizontal or at the minimum angle specified (by the owner or builder) if this is less than 30°, the angles being measured when the ship is upright and without trim, but for calculations made with derricks swung outboard the effect of heel is to be taken into account if the heel of the ship is likely to exceed 5° with the derrick booms in this position and whilst working as swinging derricks carrying the full S.W.L.

Stayed Masts and Posts

2704 The scantlings of stayed masts and stayed derrick posts are generally to be obtained from Table D 27.1 and the required size of their associated stays are to be obtained from Tables D 27.1, D 27.2 and D 27.3 by the method given in 2705 to 2711.

Where two sets of derricks with horizontal span tackle pull resultants which vary by more than 20 per cent of the higher value are fitted to the same mast, then, if the mast is a stayed mast, a full stress calculation must be submitted —*see* Note to Table D 27.1.

2705 Calculations should normally be submitted for the following conditions:—

(a) For masts with four derricks:—

(i) with two derricks plumbing one hatch;

(ii) with two derricks swung to their most outboard working position on one side of the ship.

(b) For masts with one derrick fitted forward and one aft:—

(i) with one derrick at its greatest working outreach in a fore and aft direction;

(ii) with both derricks swung to their most outboard working position on one side of the ship.

In each case the above derricks are to be considered as swinging derricks carrying the full S.W.L.

If other arrangements seem likely to give stresses significantly larger than either of the above, then a calculation is to be made for this "worst" configuration in addition to the others.

2706 The "Resultant of horizontal pulls of span tackles" is to be the resultant of the horizontal pulls of the span tackles of the derricks under load, plus any cargo runners that may be led to the mast head.

2707 The lengths of masts and posts are to be measured from the uppermost deck through which they pass to the mean intersection of the span and stay lines of action. (For this purpose, where a mast or post is supported by a deck house, the house top is to be regarded as a deck unless the house is specifically designed to give no effective support to the mast or post in both the transverse and fore and aft directions.)

Mast Scantlings

2708 The diameter and thickness of the mast or post at deck level is to be derived from Table D 27.1 for the appropriate resultant pull of span tackles and mast length. The diameter and thickness of the mast or post at the hounds are assumed to be 85 per cent of the Table values.

Stay Sizes

2709 Stay sizes are to be determined by means of two factors; "B" and "C".

Factor B is to be obtained from Table D 27.1 for the appropriate mast length and resultant pull of span tackles.

Factor C is to be obtained from Table D 27.2.

In Table D 27.2 the symbols are as follows:—

h is the horizontal spacing of the mast-head stay eyeplate and the deck (or bulwark) stay eyeplate. h may vary for each stay (*see* Fig. D 27.1 where varying values of h are shown as h_1, h_2, h_3 and h_4).

x is the horizontal distance from the deck (or bulwark) stay eyeplate to the line of action of the derrick boom (or mean line of action of the derrick booms if more than one will be in use). x may vary for each stay (*see* Fig. D 27.1).

In Fig. D 27.1 the derrick boom is shown hung on the mast. Where a boom is hung on a crosstree of normal length, the "line of action" of the boom should be transferred to the centre of the mast before measuring x and h values.

If the mast's stays are attached to a point a short way along a crosstree (*see* 2718), the line of action of the stays should be transferred to the centre of the mast before measuring x and h.

Where the stays are attached to the end of crosstrees or where derrick span blocks are attached to crosstrees at a much greater than normal distance from the mast, then a full stress calculation will be necessary.

v is the vertical spacing of the mast-head stay eyeplate and the deck (or bulwark) stay eyeplate. v may vary for each stay due to variations in deck or bulwark levels, but Table D 27.1 is only applicable if the stays are attached to the mast at or near to the same level as the span tackle.

The values of $\frac{x}{h}$ and $\frac{h}{v}$ are to be used to obtain the appropriate value of factor C for each stay.

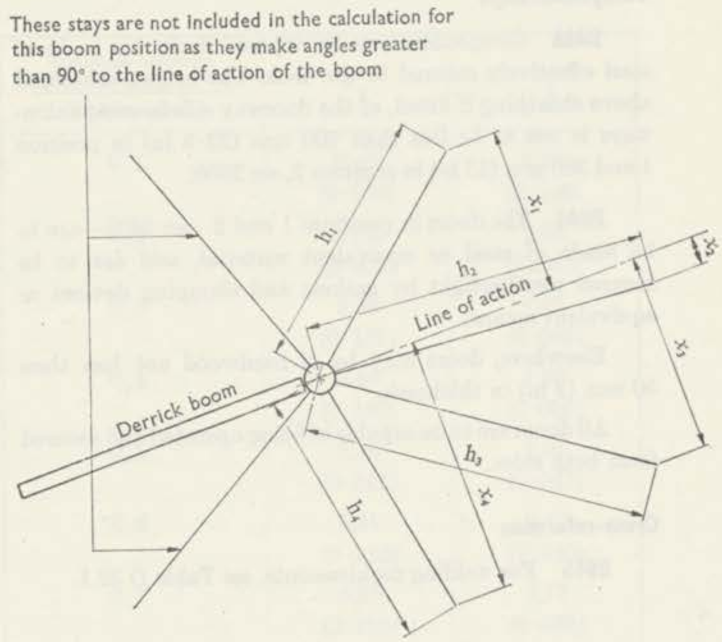


Fig. D 27.1

2710 The values of factor C for all stays are to be added and the required metallic cross sectional area of each stay is to be obtained from the following formula:—

$$\text{Area} = 645A_W = 645\,\frac{\text{Factor B}}{\text{Sum of Factors C}}\ \text{mm}^2$$

or in British units:—

$$\text{Area} = A_W = \frac{\text{Factor B}}{\text{Sum of Factors C}}\ \text{in}^2$$

This formula assumes that all stays are the same size and construction and that the heights v in no case exceed the mast length by more than 1,25 m (4·1 ft).

If v, for any particular stay, does exceed the mast length by more than 1,25 m (4·1 ft) then the metallic cross sectional area for that particular stay is to be increased in the ratio of $\frac{v}{\text{mast length}}$.

TABLE D 27.1—MAST SCANTLINGS AND FACTOR "B"

MAST LENGTH		TOTAL RESULTANT OF HORIZONTAL PULLS OF SPAN TACKLES						
		NO LOAD	5 TONNES (TONS)	10 TONNES (TONS)	15 TONNES (TONS)	20 TONNES (TONS)	25 TONNES (TONS)	30 TONNES (TONS)
metres (feet)		mm (in)	mm (in)	mm (in)	mm (in)	mm (in)	mm (in)	mm (in)
9,25 (30′ 4″)	Mast size	300×6 (11¾×0·24)	460×7,5 (18⅛×0·30)	510×9 (20⅛×0·35)	570×12 (22⅜×0·47)	630×12,5 (24¾×0·49)	700×12,5 (27½×0·49)	760×12,5 (29⅞×0·49)
	Factor B	0,030	0,112	0,265	0,439	0,680	0,939	1,246
10,75 (35′ 3″)	Mast size	360×6,5 (14⅛×0·26)	510×8 (20⅛×0·31)	570×10 (22½×0·39)	630×11,5 (24¾×0·45)	700×12 (27⅝×0·47)	760×12 (29⅞×0·47)	810×13 (31⅞×0·51)
	Factor B	0,030	0,101	0,243	0,430	0,639	0,885	1,137
12,25 (40′ 2″)	Mast size	410×7 (16⅛×0·28)	560×7,5 (22×0·30)	620×10,5 (24⅜×0·41)	670×12 (26⅜×0·47)	740×12,5 (29⅛×0·49)	790×13,5 (31⅛×0·53)	840×14 (33×0·55)
	Factor B	0,030	0,093	0,230	0,394	0,591	0,799	1,018
13,75 (45′ 1″)	Mast size	460×7,5 (18⅛×0·30)	580×8 (22¾×0·32)	650×10,5 (25⅝×0·41)	710×12 (28×0·47)	760×13 (29⅞×0·51)	810×14 (31⅞×0·55)	860×14,5 (33⅞×0·57)
	Factor B	0,030	0,082	0,217	0,368	0,538	0,730	0,927
15,25 (50′ 0″)	Mast size	510×8 (20⅛×0·31)	610×9,5 (24×0·37)	690×11 (27⅛×0·43)	740×13 (29⅛×0·51)	790×14 (31⅛×0·55)	840×14,5 (33×0·57)	900×15,5 (35⅜×0·61)
	Factor B	0,030	0,072	0,202	0,338	0,497	0,674	0,854
16,75 (54′ 11″)	Mast size	560×8,5 (22×0·34)	660×9,5 (26×0·37)	720×11 (28⅜×0·43)	790×12,5 (31⅛×0·49)	840×14 (33×0·55)	890×14,5 (35×0·57)	940×15,5 (37×0·61)
	Factor B	0,030	0,068	0,190	0,328	0,478	0,648	0,824
18,25 (59′ 10″)	Mast size	610×9 (24×0·35)	710×10 (28×0·39)	760×11 (29⅞×0·43)	810×13,5 (31⅞×0·53)	860×15 (33⅞×0·59)	910×15,5 (35⅞×0·61)	970×16 (38⅛×0·63)
	Factor B	0,030	0,059	0,180	0,304	0,443	0,600	0,774

NOTE.—When two sets of derricks with differing span tackle pulls are hung one forward and one aft of a mast, it will be possible to use Table D 27.1 only if the difference in the span pull resultants does not exceed 20 per cent of the larger pull. Within these limits the mast size chosen should be the smaller of the differing scantlings derived from the Table, but the values of factor B should be those appropriate to the span resultant in each case. Where the span resultants vary by more than 20 per cent, a full stress calculation should be made (*see* 2701).

Excessively stiff masts, i.e., masts in which the inertia is greater than that shown in the Table, should not be fitted since they will deflect less than assumed and the stays will not take their correct proportion of the load. Small reductions in mast stiffness, relative to the Table values, can be accepted provided the modulus deficiency is proportionately less than that of the inertia.

TABLE D 27.2—STAY EFFICIENCY FACTOR "C"

$\frac{x}{h}$	$\frac{h}{v}$ 0,6	0,7	0,8	0,9	1,0	1,2	1,5
0	0,227	0,269	0,308	0,333	0,353	0,377	0,384
0,1	0,225	0,267	0,304	0,330	0,350	0,372	0,380
0,2	0,217	0,258	0,294	0,318	0,338	0,361	0,367
0,3	0,206	0,243	0,278	0,301	0,320	0,341	0,347
0,4	0,189	0,225	0,257	0,278	0,296	0,315	0,321
0,5	0,171	0,202	0,231	0,250	0,265	0,283	0,288
0,6	0,145	0,172	0,196	0,212	0,225	0,241	0,245
0,7	0,117	0,139	0,159	0,172	0,183	0,195	0,198
0,8	0,082	0,097	0,111	0,120	0,128	0,136	0,139
0,9	0,044	0,052	0,059	0,064	0,068	0,071	0,073
1,0	0	0	0	0	0	0	0

TABLE D 27.3—WIRE ROPE DIAMETERS FOR VARYING VALUES OF A_W

Dia. (mm)	Circumference (inches)	Construction 6×7	6×19	7×7	7×19
		A_W	A_W	A_W	A_W
8	1	0,037	0,037	—	—
9	1⅛	0,045	0,050	—	—
10	1¼	0,057	0,059	0,067	—
11	1⅜	0,069	0,069	0,081	—
12	1½	0,088	0,089	0,104	—
14	1¾	0,116	0,114	0,137	0,135
16	2	0,150	0,154	0,176	0,184
18	2¼	0,187	0,185	0,220	0,220
20	2½	0,240	0,236	0,283	0,282
22	2¾	0,286	0,275	0,338	0,326
24	3	0,338	0,336	0,396	0,386
26	3¼	0,393	0,402	0,462	0,481
28	3½	0,466	0,452	0,550	0,541
32	4	0,598	0,587	0,703	0,701
36	4½	0,769	0,738	0,903	0,881
40	5	0,936	0,943	—	1,127
44	5½	—	1,136	—	1,352
48	6	—	1,361	—	1,604
52	6½	—	1,569	—	1,872
56	7	—	1,812	—	2,160

2711 The size of stays equivalent to various values of A_W are given in Table D 27.3 for representative wire ropes, but exact values provided by the manufacturer of any particular rope are acceptable.

Stress Calculations—Unstayed Masts and Posts

2712 Where only one derrick is to be loaded at one time (e.g. a heavy derrick on the ship's centreline), or where two derricks may be loaded at the same time but while working different hatches, the worst stresses, for rigs of normal design, can be assumed to occur with the derrick boom or booms swung outboard (on the same side of the ship if two booms are concerned).

Where two derricks are designed to work one hatch simultaneously, the worst stresses, for masts of circular section, can be assumed to occur with both booms plumbing that hatch.

2713 The reaction of a derrick heel is to be ignored when calculating the bending moment in a mast or post, unless the gooseneck, trunnion or other similar heel fitting is attached to the mast or post, or to a lower crosstree or outrigger, which is wholly supported by the mast or post.

2714 The bending moment acting at any particular point is the sum of:—

(a) Each force component acting perpendicularly to the mast or post, and parallel to the plane in which the mast or post will bend, multiplied by the distance, measured parallel to the mast or post of that force above the point under consideration.

(b) Each force component acting parallel to the mast or post multiplied by the distance (measured perpendicularly to a plane through the neutral axis of that mast or post) of that force from the plane through the neutral axis.

2715 The bending stress at each position on the mast or derrick post is to be calculated from the formula:—

$$f_B = \frac{M_m\, y}{I_m} \text{ kg/mm}^2 \text{ (ton/in}^2\text{)},$$

where f_B = bending stress at the position under consideration,

M_m = bending moment derived as specified in 2714, in mm kg (in tons),

I_m = moment of inertia of the mast at the height under consideration, in mm^4 (in^4),

y = the distance from the neutral axis of the mast to the extreme outer surface at the height under consideration, in mm (in).

2716 The direct compressive stress acting on the mast is to be calculated by summing all the vertical components of span gear, derrick thrust, etc., as applicable, and the weight of the topmast and crosstrees if fitted, and dividing the total by the cross-sectional area of the mast or post at the position under consideration.

The weight of the mast or post tube itself need not be included.

2717 The sum of bending and direct stresses derived from 2715 and 2716 is not at any point to exceed 0,55 Yor 0,35U+0,05Y whichever is the least, if the S.W.L. of no derrick boom exceeds 10 tonnes (tons). Where the S.W.L. of one or more derricks exceeds 10 tonnes (tons) then the stress may increase by 0,010Y or by 0,007U, whichever is the least, for each 4 tonne (ton) increase in the S.W.L. of the derrick with the highest S.W.L., where Y = specified minimum yield stress or 0,5 per cent proof stress and U = specified minimum tensile strength plus one half of the specified range of tensile strength. For ordinary shipbuilding mild steel Y may be taken as 25 (16) and U as 46 (29).

The stresses in crosstrees, outriggers, and similar items are to be derived as for masts but using the highest S.W.L. of any derrick actually supported by the crosstree or outrigger.

2718 The effect of torque need not be included in calculating the stresses in masts of normal design, unless the span tackle eyeplate pins to which the derricks are attached to crosstrees or outriggers, are at a distance from the mast centreline exceeding $\frac{D^2 \text{ mm}}{25{,}4 \text{ S.W.L.}} \left(\frac{D^2 \text{in}}{\text{S.W.L.}}\right)$ where D is the mast diameter at half height in mm (in). S.W.L. is the highest safe working load of any derrick supported by the crosstree or outrigger in question, in tonnes (tons).

When torque is taken into account it is to be taken as:—

T = horizontal component of span tension $\times$ distance from span eye to centreline of mast or post in tonne mm (ton in).

Shear stress is to be taken as $q = \frac{T}{2At}$, where A is the total area enclosed by the outer surface of the mast or post $\left(\text{for circular masts; } A = \frac{\pi \text{ (diameter)}^2}{4}\right)$ mm^2 (in^2) and t is the wall thickness of the mast or tube, in mm (in.)

The total stress in the mast or post is:—

$$f_t = 0{,}5\left(f_m + \sqrt{(f_m)^2 + 4q^2}\right) \text{ kg/mm}^2 \text{ (ton/in}^2\text{)}$$

where f_m is the stress value derived from 2717.

2719 The wall thickness, in mm (in), of oval or circular masts and posts is not to be less than:—

$$\frac{FD\sqrt{KY}}{350 + 2 \times S.W.L.} \quad \text{or} \quad \frac{FD}{100} \qquad (1)$$

whichever is the greater,

where D = maximum outside diameter of the mast at corresponding height above the deck, in mm (in),

$F = \sqrt{\dfrac{\text{Actual Calculated Stress}}{\text{Maximum Permitted Stress}}}$

$K = 1{,}00\ (1{\cdot}58)$,

Y = yield stress, in kg/mm² (ton/in²),

S.W.L. = maximum safe working load of any derrick supported by the mast, in tonnes (tons).

The wall thickness, in mm (in), of unstiffened flat sides of masts or posts, with one or more flat sides, is not to be less than:—

$$\frac{FW\sqrt{KY}}{200 + 2 \times S.W.L.} \quad \text{or} \quad \frac{FW}{60} \qquad (2)$$

whichever is the greater,

where K, Y F, and S.W.L. are as defined above and W is the width, in mm (in), of the flat side at that height or 60 per cent of the width of the mast at that height, measured parallel to the flat side, whichever is the greater.

Where masts are constructed of a combination of curved and flat plates, e.g., curved sides and flat front and back, the value $\frac{FW}{60}$ may be used in determining the minimum thickness if this is more favourable than $\frac{FD}{100}$ for the curved plates.

Where flat sides of masts or posts are fitted with vertical stiffeners effectively restrained against tripping, then the values of W used in the formulæ may be taken as the stiffener spacing.

Attention is drawn to the fact that this paragraph is designed to prevent local buckling of the mast plating under compression loading, assuming some local initial unfairness in the plating, and if stiffeners are fitted to permit reductions in plate thicknesses, then they should not be liable to instability under end loading.

Fittings and Details

2720 Masts and derrick posts are to be increased in thickness at the heel and decks and other points of support, and are to be suitably strengthened to take any concentrated loads which may be expected to occur in way of derrick fittings, crosstrees and ventilation openings. They should normally be attached to at least two decks other than the tops of winch houses and small deck houses of a type giving no effective support, but need not be attached to more than two decks or one deck and the top of a substantial house.

The heels of masts and derrick posts are to be effectively supported.

2721 The design and construction of masts, posts and fittings is to be such as to reduce the likelihood of water collecting in inaccessible parts of the structure.

2722 For lightning conductors, *see* M 19.

Workmanship

2723 Smithwork should be of a material not liable to work hardening or ageing to a significant degree during normal use.

Rimming steel should not be used.

Where fittings are flame cut from solid material they are to be annealed after cutting and all flame cut faces are to be ground if necessary to give a smooth finish to avoid stress raisers.

Crosstrees

2724 Where outriggers or crosstrees at mast-heads are of unusual spread or where stays are attached to the crosstrees well clear of the mast, the scantlings of the mast and rigging will be specially considered.

The stresses in crosstrees should not normally exceed 55 per cent of the yield stress of the material or (for items under compression) of the crippling stress of that item.

Section 28

BULWARKS, FREEING PORTS, SCUPPERS AND SANITARY DISCHARGES AND SIDE SCUTTLES

Bulwarks

2801 The height of plate bulwarks on exposed parts of freeboard and superstructure decks, measured above sheathing if fitted, is to be at least 1,0 m (39·5 in) except that where this height would interfere with the normal operation of the ship a lesser height may be approved.

2802 Plate bulwarks are to be stiffened by a strong rail section and supported by stays from the deck. The spacing of these stays forward of 0,07L from the fore perpendicular is not to be more than 1,2 m (4 ft) on Types "A" "B-60" and "B-100" ships and not more than 1,83 m (6 ft) on other types. Elsewhere, bulwark stays are not to be more than 1,83 m (6 ft) apart. Where bulwarks are cut to form a gangway or other opening, stays of increased strength are to be fitted at the ends of the openings. Bulwarks are to be adequately strengthened in way of eyeplates for cargo gear and in way of mooring pipes the plating is to be doubled or increased in thickness and adequately stiffened.

2803 The arrangements for continuity of strength at the ends of superstructures are to be as required by D 1715. Bulwarks should not be cut for gangway or other openings near the breaks of superstructures and are also to be arranged to ensure their freedom from main structural stresses. (*See* D 510.)

Freeing Ports

2804 Where bulwarks on the weather portions of freeboard or superstructure decks form wells, ample provision is to be made for rapidly freeing the decks of large quantities of water by means of freeing ports and also for draining them.

2805 The minimum freeing port area on each side of the ship, for each well on the freeboard deck (including raised quarter decks), where the sheer in way of the well is standard or greater than standard, is to be as given by the following formulæ. (*See also* 2807.)

(*a*) Where the length (l), of the bulwark in the well is 20 m (66 ft) or less:—

Area required$=0{,}7+0{,}035\ l$ m^2

(Area required$=7\cdot6+0\cdot115\ l$ ft^2)

(*b*) Where the length (l) exceeds 20 m (66 ft):—

Area required$=0{,}07\ l$ m^2

(Area required$=0\cdot23\ l$ ft^2)

l need not be taken greater than 0,7L.

If the average height of the bulwark exceeds 1,2 m (3·9 ft) or is less than 0,9 m (3 ft) the freeing port area is to be increased or decreased respectively by 0,004 m^2 per metre of length of well for each 0,1 m difference (0·04 ft^2 per foot of length of well for each foot difference) in height from Rule.

The minimum freeing port area for each well on superstructure decks is to be one half of the area given by the above.

Type "B" ships with reduced freeboards will require to have freeing port area greater than given above.

2806 In ships with no sheer the freeing port area is to be increased by 50 per cent. Where the sheer is less than the standard, the percentage is to be obtained by interpolation.

2807 Where ships are fitted on the freeboard deck with a continuous trunk or continuous hatchside coaming in association with bulwarks, the minimum area of freeing port openings is to be not less than 20 per cent of the total area of bulwarks when the width of trunk or hatch is 0,4B or less and not less than 10 per cent of the total area of bulwarks when the width of the hatch is 0,75B or more, with intermediate values by interpolation.

2808 Adequate provision is to be made for freeing water from superstructures which are open at either or both ends and from all other decks within open or partially open spaces in which water may be shipped and contained.

2809 Two-thirds of the freeing port area required is to be provided in the half of the well nearest to the lowest point of the sheer curve.

2810 The lower edges of freeing ports are to be as near to the deck as practicable and the openings are to be protected by rails spaced approximately 230 mm (9 in) apart. If hinged shutters are fitted to freeing ports ample clearance is to be provided to prevent jamming, and if securing appliances are fitted these appliances are to be of approved construction. Hinges are to have pins or bearings of non-corrodible material.

Scuppers and Sanitary Discharges

2811 Scuppers sufficient in number and size to provide effective drainage are to be fitted in all decks.

2812 In ships over 150 m (492 ft) in length, scupper openings are not to be cut in the sheerstrake above deck level within 0,5L amidships, and in no case in way of discontinuities such as breaks of superstructures. (*See* D 510.)

When scuppers or discharges are cut in the shell or superstructure sides compensation may require to be fitted.

2813 Scuppers and discharges which drain spaces below the freeboard deck or spaces within intact superstructures or deckhouses on the freeboard deck fitted with efficient weathertight doors, may be led to the bilges in the case of scuppers or to suitable sanitary tanks in the case of sanitary pipes. Alternatively, they may be led overboard provided the spaces drained are above the load waterline, and the pipes are fitted with efficient and accessible means of preventing water from passing inboard. (*See* 2814.)

2814 In general, each separate overboard discharge is to be fitted with a screw-down non-return valve capable of being operated from a position always accessible and above the freeboard deck. An indicator is to be fitted at the control position showing whether the valve is open or closed.

Where, however, the vertical distance from the summer load waterline to the inboard end of the discharge pipe exceeds 0,01L the discharge may be fitted with two automatic non-return valves without positive means of closing, instead of the screw-down non-return valve, provided the inboard valve is always accessible for examination under service conditions.

Where the vertical distance from the summer load waterline to the inboard end of the discharge pipe exceeds 0,02L, consideration will be given to proposals for fitting a single automatic non-return valve without positive means of closing.

2815 Scuppers and discharge pipes originating at any level, which penetrate the shell either more than 450 mm (17·5 in) below the freeboard deck or less than 600 mm (23·5 in) above the summer load waterline are to be fitted with an automatic non-return valve at the shell.

This valve, unless required by 2813, may be omitted provided the pipe thickness is not less than:—

$$\frac{\text{Diameter of pipe in mm}}{24} + 6{,}5\ \text{mm}$$

$$\left(\frac{\text{Diameter of pipe in inches}}{24} + 0{\cdot}25\ \text{in}\right)$$

but need not exceed 12,5 mm (0·50 in).

2816 Scuppers draining weather decks and spaces within superstructures or deckhouses not fitted with efficient weathertight doors are to be led overboard.

2817 Plans showing the arrangement of scuppers for draining refrigerated cargo compartments are to be submitted for consideration.

Materials for Valves and Pipes

2818 All castings and all elbow pieces where no valves are required, are to be of approved material other than ordinary cast iron or similar non-ductile material.

The lengths of pipe attached to the required valves or elbow pieces are to be of galvanised steel of standard steam pipe quality or other equivalent approved material. *See also* F 706.

Protection of Pipes and Valves

2819 In all cargo spaces and other areas where damage might be likely, all scuppers and discharges including their valves, controls and indicators are to be well protected. This protection is to be of steel in bulk cargo spaces or their equivalent, and also in areas where contact with large containers, fork lift trucks or similar items is a possibility.

Side Scuttles

2820 Side scuttles, together with their glasses if fitted, and deadlights, are to be of approved design and of approved material other than ordinary cast iron. They are to be metal framed and glasses are to be retained by a metal glazing bead.

2821 Side scuttles to spaces below the freeboard deck or to spaces within enclosed superstructures are to be fitted with efficient inside deadlights permanently attached and capable of being closed and secured watertight.

2822 No side scuttle is to be fitted in a position so that its sill is below a line drawn parallel to the freeboard deck at side and having its lowest point 2,5 per cent of the breadth B above the load waterline or 500 mm (19·5 in) whichever is the greater distance.

2823 In passenger ships, the position and construction of the side scuttles will be specially considered. (*See also* F 813.)

Section 29

VENTILATION, AIR PIPES AND SOUNDING PIPES

Ventilator Coamings

2901 The minimum height of ventilator coamings above the upper surface of decks exposed to the weather, measured above sheathing if fitted, is to be as follows:—

Ventilators situated in position 1 (*see* D 2605) 900 mm (35·5 in),

Ventilators situated in position 2 (*see* D 2605) 760 mm (30 in).

Where it is intended to fit patent ventilators the minimum height of coaming will be specially considered.

2902 Ventilator coamings having a height greater than 900 mm (35·5 in) are to be specially supported.

2903 The thickness of steel ventilator coamings is to be not less than:—

$$5{,}5 + \frac{\delta}{100}\ \text{mm} \qquad \left(0{\cdot}22 + \frac{\delta}{100}\ \text{in}\right)$$

where δ is the internal diameter of the coaming. The thickness need not exceed 10 mm (0·40 in), but is not to be less than 7,5 mm (0·30 in).

2904 The deck plating in way of ventilator coamings is to be efficiently stiffened.

2905 All ventilator coamings are to be provided with strong plugs and canvas covers or equally efficient weathertight closing appliances unless (a) the height of the coaming is greater than 4,5 m (14·8 ft) where 2901 requires a minimum height of 900 mm (35·5 in), or (b) the height of the coaming is greater than 2,3 m (7·5 ft) where 2901 requires a minimum height of 760 mm (30 in).

These closing appliances are to be either permanently attached to the ventilator coaming or else stowed in a convenient and accessible position close to the coaming for which they are intended to be used.

2906 In particularly exposed positions the heights, scantlings and/or supports of ventilator coamings may be required to be suitably increased above the values given above.

Positioning of Ventilators

2907 Special care is to be taken when designing and positioning ventilator openings and coamings, particularly in the region of the forward end of superstructures and other points of high stress.

Where practicable, ventilators should be sited clear of highly stressed parts of the structure. In general, ventilation openings should not be cut in deck girders within 1,5 m (5 ft) of pillars or of the girder endings.

Minor Ventilators

2908 Mushroom, gooseneck and other similar minor ventilators are to be strongly constructed and efficiently secured to the deck plating.

Fire Precautions

2909 For passenger ships, *see* F 815 to F 817.

For cargo ships, *see* F 1004.

Air and Sounding Pipes

2910 Air and sounding pipes are to comply with the requirements of Chapter E.

2911 The height of air pipes from the upper surface of decks exposed to the weather, to the point where water may have access below is not normally to be less than:—

On the freeboard deck ... 760 mm (30 in),

On superstructure decks ... 450 mm (17·5 in).

These heights are to be measured above sheathing, where fitted.

Lower heights may be approved in cases where these are essential for the working of the ship, provided the design and arrangements are otherwise satisfactory.

2912 All openings of air and sounding pipes are to be provided with permanently attached satisfactory means of closing to prevent the free entry of water.

2913 Striking plates of suitable thickness, or their equivalent, are to be fitted under all sounding pipes.

2914 Air and sounding pipes are to be well protected in all spaces. This protection is to be of steel in bulk cargo spaces or their equivalent, and also in areas where contact with large containers, fork lift trucks or similar items is a possibility.

Section 30

CEILING AND CARGO BATTENS

Ceiling

3001 In ships having double bottoms, ceiling is to be laid over the bilges and under hatchways; the ceiling over the bilges is to be arranged with portable sections that are readily removable. Ceiling under hatchways may be omitted provided the thickness of the inner bottom plating is increased by 2 mm (0·08 in).

3002 The spaces between the frames at the top of the bilge ceiling are to be closed by wood chocks and cement or other suitable means.

3003 Ceiling is to be laid either directly on the inner bottom plating embedded in a suitable bituminous or epoxy composition, or on battens providing a clear space of at least 12,5 mm (0·5 in) for drainage.

3004 The thickness of wood ceiling is not to be less than 65 mm (2·5 in).

Where it is intended to use plywood or other forms of ceiling of an approved type instead of planking, the thickness will be considered for each case.

3005 Where the covers or fittings of the manholes of the inner bottom in cargo holds project above the plating, they are to be protected by a steel coaming around each manhole, fitted with a hatch of wood or steel.

Cargo Battens

3006 Cargo battens are to be fitted in the holds from above the upper part of the bilge to the under side of beam knees, and in all cargo spaces in 'tween decks and superstructures up to the under side of beam knees.

3007 Wood cargo battens are to be 50 mm (2 in) in thickness; the clear space between adjacent rows is, in general, not to exceed 230 mm (9 in).

If it is intended to use other materials instead of battens, the thickness will be considered in each case.

3008 Battens may be dispensed with at the request of the Owners; the notation "NS" will appear in the Register Book.

Cross-references

3009 For ceiling in ships which are regularly discharged by grabs, *see* D 907.

For arrangements in way of refrigerated holds, *see* N 415 and N 416.

Section 31

PROTECTION OF STEELWORK

Cementing

3101 In double bottom tanks under the boiler room, the frames and shell plating are to be effectively covered by an approved type of cement or other coating unless the tanks are used solely for oil fuel; elsewhere in the double bottom the cement or coating may be dispensed with, but the requirements of 3102 would then apply. The bilges are to be cemented or effectively coated.

Painting

3102 All steelwork not protected as required by 3101 is to receive at least two coats of paint of suitable composition except inside tanks intended for oil; tanks not intended for oil may be coated with cement wash as an alternative to painting. (*See* F 822 and F 1005).

An approved system of corrosion control may be adopted in tanks as an alternative to painting. (*See* D 110.)

General

3103 Millscale should be removed from external shell plating, and it is recommended that shot blasting, pickling or other equally effective means be employed for this purpose. If flame cleaning is adopted, it is to be followed by wire brushing or grinding. Where reliance is placed on weathering and wire brushing, the coating of the external surface should be delayed as long as possible to facilitate the removal of the millscale.

3104 When the millscale is removed by methods less effective than shot blasting, it is desirable, when several months elapse between the launching and commissioning, to dry dock the ship immediately before she goes into service. In these circumstances, it is also desirable to dry dock a ship when she has been in service about six months.

Section 32

WELDING

General

3201 Where electric arc welding is to be used for the main structure the arrangement of plating, disposition and type of joints, together with the proposed sequence of prefabrication, assembly and welding are to be submitted for approval. The extent to which automatic welding (whether deep penetration or otherwise) is to be used should be indicated.

Details of welded connections of main structural members with type and size of welds are to be clearly indicated on the plans submitted for approval.

The approved arrangements, sequences and procedures are not to be departed from without approval.

3202 The structural arrangements are to be such as will admit of easy access for welding operations and facilitate the use of downhand welding wherever possible.

The type and disposition of connections and sequences of welding are to be so planned that any restraint during welding operations is reduced to a minimum.

3203 The electrodes used are to be approved by the Committee and are to be suitable for the type of joint and grade of steel as follows:—

Grade 1—for Grade A steel,

Grade 2—for Grades A or D steel,

Grade 3—for Grades A, D or E steel.

When joining two different grades of steel of the same tensile properties, electrodes suitable for the lower grade are generally acceptable, except at discontinuities or other points of stress concentration. The requirements for electrodes are given in P 11.

Primers and Coatings

3204 Where primers are applied over areas which will subsequently be welded they are to be of a quality approved by the Society as having no deleterious effect on the finished weld.

Inspection

3205 Effective arrangements are to be provided for the inspection of finished welds in order to ensure that all welding has been satisfactorily completed.

Visual inspection may require to be supplemented by other forms of non-destructive crack or flaw detection methods for the examination of important structural welds. The extent of such examination is to be to the Surveyor's satisfaction but particular attention should be paid to the following locations:—

(a) Junction and crossings of seams and butts in strength deck, sheerstrake, side and bottom shell within 0,4L amidships,

(b) Butts of keel plating and rounded sheerstrake within 0,4L amidships,

(c) Insert plates in way of hatch openings in the strength deck.

A system of radiographic examination should be used wherever practicable and where this is available the Surveyors are to collaborate with the Builders in this system of inspection. (*See also* 3219 (f) for higher tensile steel).

All defective sections of welds are to be cut out, carefully re-welded and re-examined.

3206 Alternative proposals for methods of welding considered by the Committee to be equivalent to those set forth in the Rules will be accepted.

Joints and Connections

3207 BUTT WELDS In general, the edges of plates to be joined by manual welding are to be bevelled on one side or on both sides of the plates to provide an included angle of from 50 to 60 degrees.

Where it is desired to adopt other forms of edge preparation full details are to be submitted for approval.

A back sealing run is to be applied, after suitable back gouging, to all butt welds where main welding is carried out from one side only, unless the welding process has been specially approved for use without a back run.

3208 FILLET WELDS The dimensions of fillet welds for structural connections are to be as required by Table D 32.1 and associated notes.

3209 TEE CONNECTIONS The throat thickness (leg length) of the fillets is generally to be governed by the thickness of the thinner of the two parts being joined.

Where the difference between the thicknesses of the parts to be joined is considerable, the size of the fillet will be specially considered (*see* Table D 32.1 Note 1 for slab type longitudinals).

Tee connections should be made by fillets on both sides of the abutting plate. Where the abutting plate is bevelled a sealing run should be applied on the reverse side.

3210 INTERMITTENT FILLETS The length of intermittent welds is to be measured over the correctly proportioned fillet, clear of end craters.

Intermittent welds are to be doubled at the ends of all structural members, and the welding is to be carried round the ends of brackets, lugs, etc.

3211 SCALLOPS AND NOTCHES The details of scalloped construction are given in Fig. D 32.1. All scallops are to have well rounded corners and smooth edges. Scallops are not to be cut in way of the toes of bracket connections or at other parts where stress concentrations may develop.

Scallops in side frames, longitudinals and stiffeners are to be omitted for at least 230 mm (9 in) on each side of the intersection with a primary supporting member.

Notches in primary supporting members are not to be larger than necessary, and are to have well rounded corners and smooth edges. When notches occur at points where stress concentration may develop, such as adjacent to the toes of brackets, a welded collar or equivalent reinforcement is to be fitted.

Additional Attachment

3212 Welded connections may require to be increased to meet particular local stresses, or where otherwise necessary.

Workmanship

3213 Welding operators are to be proficient in the type of work on which they are engaged. A sufficient number of skilled supervisors is to be provided to ensure effective control at all stages of assembly and welding operations. The welding plant and appliances are to be suitable for the purpose intended and are to be maintained in an efficient condition.

3214 Procedures for the welding of all joints are to be established for the types of electrode, edge preparation and welding position proposed. For this purpose, the Surveyors may require sample tests to be prepared under similar conditions to those which will obtain during construction.

The diameter of electrode, current, voltage, rate of deposit and number of runs are to conform, as far as practicable, to those established in accordance with 3213. Provision is to be made for checking the current in the vicinity of the arc.

3215 The preparation of plate edges is to be accurate and uniform. All joints are to be properly aligned and closed or adjusted before welding. Excessive force is not to be used in fairing and closing the work. Means are to be provided for holding the work in proper alignment without rigid restraint during welding operations.

Where excessive gaps exist between surfaces or edges to be joined, the corrective measures adopted are to be to the satisfaction of the Surveyors.

3216 Tack welding should be kept to a minimum and where used should be equal in quality to the finished welds. All defective tack welds should be cut out before completing the finished welds.

Care should be taken when removing tack welds and temporary fittings used for assembly to ensure that the material of the hull is not damaged.

3217 The surfaces of all parts to be welded are to be clean, dry and free from rust, scale and grease. The surfaces and boundaries of each run of deposit are to be thoroughly cleaned and freed from slag before the next run is applied.

Before a manual sealing run is applied to the back of a weld the original root run is to be cut back to sound metal.

Welding is to proceed systematically, each welded joint being completed in proper sequence without undue interruption.

Adequate protection is to be provided where welding is required to be carried out in exposed positions in wet, windy or cold weather. In cold weather, precautions should be taken to screen and pre-warm the work where necessary to prevent too rapid cooling of the weld; special care is necessary when welding thick material.

3218 All finished welds are to be sound, uniform and substantially free from slag inclusions, porosity, undercutting or other defects. Care is to be taken to ensure thorough penetration and fusion.

Welding of Higher Tensile Steel

3219 Where higher tensile steel is employed the requirements as laid down in this section are to be carried out in so far as they are applicable, with the following amendments:—

(*a*) Electrodes are to be of a type approved by the Society for use with higher tensile steel,

(*b*) Welding procedures and techniques are to be demonstrated as satisfactory by shipyard tests (*See* 3214),

(*c*) Preheating and/or other heat treatment during or after welding may be required where conditions of high restraint are unavoidable, or when the ambient temperature is unusually low, or more generally, when desirable due to the design of the weld, size of electrode, and the thickness and chemical analysis of the steel being welded,

(*d*) Fillet welds are to be continuous,

(*e*) Butt welds are to have a smooth profile without excessive build-up,

(*f*) Random non-destructive testing is to be carried out especially at highly stressed items. Magnetic crack detecting or equivalent tests are to be used at the ends of fillet welds, tee joints and other joints where welds join or cross in main structural members. Butt welds and highly stressed items elsewhere are to be X-rayed or given other equivalent tests.

3220 Where the structure incorporates both mild steel and higher tensile steel details of the welding arrangements and procedures at the interchange joints are to be submitted for approval in all cases where the chemical analysis of the higher tensile steel requires that it be preheated or heat treated after welding.

Welding of Aluminium Alloys

3221 Where welding of aluminium alloys is employed, the requirements as laid down in this section are to be carried out in so far as they are applicable, with the following additions:—

The edges of the material to be welded are to be clean and freed from grease by chemical or solvent cleaning. The joint edges should be scratch brushed—preferably immediately before welding—in order to remove oxide or adhering films of dirt, filings, etc.

Parts to be welded should be set up in such a way that contraction stresses are kept to a minimum.
For welding processes and filler wire, *see* P 14.

TABLE D 32.1

DETAILS OF VARIOUS FILLET WELD CONNECTIONS

ITEM	*WELD FACTOR	REMARKS
TRANSVERSE FRAMING		
Hold frames (including ice frames) to shell ...	*See* D 733	continuous in way of beam knees and tank side brackets
	0,10 (0·14)	elsewhere: frame spacing less than 850 mm (33·5 in)
	0,12 (0·17)	elsewhere: frame spacing 850 mm (33·5 in) or more
Side frames in deep tanks, oil fuel tanks and in panting region	0,12 (0·17)	excluding 'tween decks
'Tween deck frames to shell	0,10 (0·14)	
Bottom frames to shell and floors, and floor plates to shell	0,12 (0·17)	in fore peaks
	0,21 (0·30)	in way of strengthened bottom forward (*see* D 1007)
	0,21 (0·30)	in aft peaks (*see* note 5)
	0,10 (0·14)	elsewhere
Floors and crossties to frames in fore peak ...	0,10 (0·14)	
Floors and crossties to frames in aft peak ...	0,21 (0·30)	*see* note 5
Frames to tank side brackets...	*See* D 733	
DOUBLE BOTTOMS (TRANSVERSELY FRAMED)		
Centre girder to keel	0,35 (0·50)	if watertight
	0,26 (0·37)	elsewhere
Centre girder to inner bottom...	0,35 (0·50)	if watertight
	0,26 (0·37)	in engine space and under thrust blocks (no scallops)
	0,21 (0·30)	elsewhere (no scallops)
Non-watertight floors to centre girder ...	0,26 (0·37)	under engine, thrust and boiler bearers
	0,14 (0·20)	elsewhere
Non-watertight floors to margin plate ...	To depend on design	generally 0,44 (0·63) in panting region and 0,35 (0·50) elsewhere
Non-watertight floors elsewhere and non-watertight side girders	0,21 (0·30)	in way of strengthened bottom forward (*see* D 1007)
	0,21 (0·30)	to inner bottom under engine and thrust bearers
	0,10 (0·14)	elsewhere
Longitudinal foundation girders under main diesel engines	—	In general, full penetration welding is required
Reversed frames to bracket floors and inner bottom	0,21 (0·30)	under engine and thrust bearers
	0,10 (0·14)	elsewhere
Tank side brackets to tank top and margin plate	0,44 (0·63)	in panting region
	0,35 (0·50)	elsewhere—generally
Tank top or margin plate to shell	0,35 (0·50)	
Boundaries of watertight and oiltight floors, side girders or double bottom wells ...	0,35 (0·50)	
Stiffeners of watertight and oiltight floors, side girders or double bottom wells	0,14 (0·20)	
For bottom frames to shell and floor plates to shell		*see* TRANSVERSE FRAMING above
LONGITUDINAL FRAMING AND DOUBLE BOTTOMS LONGITUDINALLY FRAMED		
Side longitudinals in holds, tanks and 'tween decks	0,12 (0·17)	in panting region, in tanks and where spacing exceeds 850 mm (33·5 in) (*see* note 1 and note 5)
	0,10 (0·14)	elsewhere (*see* note 1)

*Weld sizes in metric units are based upon throat thickness and in British units on leg length.

TABLE D 32.1—*continued*

ITEM	*WELD FACTOR	REMARKS
LONGITUDINAL FRAMING AND DOUBLE BOTTOMS LONGITUDINALLY FRAMED—*continued*		
Web frames supporting side longitudinals ...	0,17 (0·24)	generally to shell. Up to 0,35 (0·50) when highly loaded. Continuous in way of end brackets
	0,12 (0·17)	to face bars or face plates of area greater than 39 cm² (6 in²)
	0,10 (0·14)	elsewhere
Bottom longitudinals to shell and floors ...	0,12 (0·17)	for 0,25L forward (*see* note 1 and note 5)
	0,10 (0·14)	elsewhere (*see* note 1 and note 5)
Bottom longitudinals of the flat bar or plate type to shell ...	0,25 (0·35) Continuous weld	but need not exceed 5,5 mm (0·30 in) hand, or 4,5 mm (0·25 in) automatic. *See also* note 1
Tank top longitudinals to inner bottom ...	0,12 (0·17)	under ore holds (*see* note 1 and note 5)
	0,10 (0·14)	elsewhere (*see* note 1 and note 5)
Hopper tank and wing tank longitudinals ...	0,12 (0·17)	*see* note 1 and note 5
Non-watertight floor boundaries ...	0,12 (0·17)	
	0,26 (0·37)	for 2 spaces at ends (*see* D 1007 for fore end).
Watertight and oiltight floor boundaries ...	0,35 (0·50)	
Tank top, margin plate and girders to shell to be	as for double bottoms	(transversely framed) above
DECKS, BEAMS AND DECK LONGITUDINALS		
Strength deck to shell ...	—	full penetration weld
Other decks to shell and other boundaries ...	depends on design	generally 0,21 continuous (0·30 continuous)
Cantilever beams to deck ...	depends on design	generally 0,21 or 0,14 (0·30 or 0·20)
Cantilever brackets to deck and shell ...	0,44 (0·63)	continuous
Cantilever bracket face bar ...	0,21 (0·30)	continuous
Cantilever beam and bracket stiffeners ...	0,14 (0·20)	
Hatch end strong beams to deck ...	0,14 (0·20)	
Beams at crown of deep tanks, fuel bunkers and fore peak tank to deck...	0,12 (0·17)	*see* note 5
Beams at crown of after peak to deck ...	0,21 (0·30)	*see* note 5
Transverse beams to deck ...	0,10 (0·14)	
Longitudinals to deck ...	0,10 (0·14)	*see* note 1 and note 5
Deck longitudinals of the flat bar or plate type to deck plating...	0,25 (0·35) Continuous weld	but need not exceed 5,5 mm (0·30 in) hand, or 4,5 mm (0·25 in) automatic. *See also* note 1 continuous
Beam knees ...	*See* D 733	
Lugs and brackets on half beams to hatch coamings and casings ...	—	6,5 cm² (1 in²) of welding for beams not exceeding 200 mm (8 in) and 9,5 cm² (1·5 in²) of welding for beams exceeding 200 mm (8 in) depth
DECK GIRDERS, TRANSVERSES AND WEBS		
Connections to plating ...	0,21 (0·30)	continuous in way of end brackets
	0,14 (0·20)	elsewhere
End brackets ...	0,35 (0·50)	generally continuous
Web to face bars ...	0,12 (0·17)	face bar area greater than 39 cm² (6 in²)
	0,10 (0·14)	face bar area not exceeding 39 cm² (6 in²)
DEEP TANKS, PEAK TANKS AND BUNKERS		
Bulkhead boundary connections ...	0,39 (0·55)	at bottom and bilge (*see* note 5)
	0,35 (0·50)	at deck and side (*see* note 5)
	0,44 (0·63)	at ends of swedges (*see* D 1817)
Stiffeners ...	0,12 (0·17)	*see* D 1817 and D 1910
Stiffener brackets ...	—	*see* note 6, D 1817 and D 1910
Horizontal girders to shell and bulkheads ...	0,26 (0·37)	in way of end brackets
	0,14 (0·20)	clear of end brackets
Horizontal girders to girder brackets ...	0,26 (0·37)	generally continuous
Girder webs to face bars ...	0,12 (0·17)	face bar area greater than 39 cm² (6 in²)
	0,10 (0·14)	face bar area not exceeding 39 cm² (6 in²)

*Weld sizes in metric units are based upon throat thickness and in British units on leg length.

TABLE D 32.1—*continued*

ITEM	*WELD FACTOR	REMARKS
WATERTIGHT BULKHEADS, FLATS AND TUNNELS		
Bulkhead boundary connections	0,35 (0·50)	if thickness less than 6 mm (0·24 in) (*see* note 2 to Table D 32.1)
Stiffeners	0,10 (0·14)	generally (*see* note 5)
Stiffeners used as pillars	0,14 (0·20)	when supporting pillars above
Ends of unbracketed stiffeners	0,44 (0·63)	as required by D 1817
Brackets and lugs	—	*see* note 6 and D 1817
DECKHOUSES		
Connections to deck	0,35 (0·50)	
Stiffeners	0,10 (0·14)	
Stiffener end connections	—	*see* note 6, Table D 17.4 and Table D 17.5
NON-WATERTIGHT BULKHEADS		
Boundary connections to tank top	0,14 (0·20)	no scallops
Boundary connections elsewhere	0,10 (0·14)	
Stiffeners used as pillars	0,14 (0·20)	when supporting pillars above
Stiffeners elsewhere	0,10 (0·14)	
PILLARS		
Pillars built of rolled sections or plates ...	0,10 (0·14)	up to 0,35 (0·50) in special cases—*see also* D 1410
End connections of widely spaced pillars ...	0,35 (0·50)	*see also* D 1410
Bulkhead stiffeners acting as pillars supporting pillars above	0,14 (0·20)	*see also* D 1817
HATCHWAYS		
Coaming to deck	0,35 (0·50)	generally
Coaming to deck at corners	0,44 (0·63)	
Coaming stiffeners	0,10 (0·14)	may be increased in special cases
Hatch beam bars and face plates to webs, and stiffeners of pontoon covers...	0,10 (0·14)	generally—may be increased in special cases
VENTILATORS		
Coaming connection to weather decks ...	0,35 (0·50)	
Elsewhere	0,21 (0·30)	
STEMS AND STERNFRAMES		
Stem breasthooks and stiffeners	0,21 (0·30)	
Sternframes (main load-bearing items) ...	0,44 (0·63)	
Sternframes elsewhere	0,21 (0·30)	
RUDDERS		
Fabricated mainpiece and mainpiece to rudder side plates and webs...	0,44 (0·63)	
Elsewhere	0,21 (0·30)	
Slot welding	0,44 (0·63)	
MASTS		
Main structure	0,44 (0·63)	
Cargo gear fittings	full penetration generally required	
Minor fittings	0,21 (0·30)	

*Weld sizes in metric units are based upon throat thickness and in British units on leg length.

NOTES.—TABLE D 32.1

1. Thickness to be used in determining throat thickness (leg length) is generally to be that of the thinner of the two parts being joined.

Where slab type longitudinals are fitted to the bottom shell or upper deck within 0,4L amidships the thickness used to determine the throat thickness (leg length) is not to be taken as less than half the thickness of the longitudinal.

Where the difference between the thicknesses of the parts to be joined is considerable the size of fillet will be specially considered.

2. Throat thickness (leg length) for double continuous fillets is to be the product of the plate thickness and the weld factor given in Table D 32.1 except that where automatic deep penetration welds are used the values so derived may be reduced by 15 per cent. In no case (except for slab type longitudinals) is the throat thickness (leg length) to be less than 0,21 × plate thickness (0·30 × plate thickness) nor is it to be less than 3,5 mm (0·18 in) for hand and automatic welding or 3 mm (0·16 in) for automatic deep penetration welding.

For hand welded fillet welds on internal bulkheads not exceeding 6 mm (0·24 in) in thickness a minimum throat thickness (leg length) of 3 mm (0·16 in) is acceptable.

3. Throat thickness (leg length) for intermittent fillets is to be as given by the formula:—

Throat thickness (leg length) = plate thickness × weld factor $\times \frac{d}{s}$ where d and s are defined in Fig. D 32.1

The length s should not be less than 75 mm (3 in) and the ratio of s and d is to be such that the required throat thickness (leg length) does not exceed 0,49 × plate thickness (0·70 × plate thickness) or 4,5 mm (0·24 in) whichever be the greater.

In no case, however, is the throat thickness (leg length) of intermittent fillet welds to be less than 0,28 × plate thickness (0·40 × plate thickness) or 3,5 mm (0·18 in) whichever be the greater.

4. Leg length of welds is to be not less than 140 per cent of the throat thickness derived as above.

or in British units:—

Throat thickness of welds is to be not less than 70 per cent of the leg length derived as above.

5. Fillet welds in after peak tanks and on after peak bulkhead stiffeners and all welding in deep tanks intended for chemicals and edible liquids are to be continuous. Where the thickness of bottom or deck longitudinals exceeds the thickness of the shell or deck plating the welding is to be continuous. (*See also* D 1007).

6. Welding at the ends of bulkhead stiffeners, etc. (whether associated with brackets or lugs) is to give, generally, a weld area (length of weld × throat thickness) of 25 per cent of the cross sectional area of the stiffener with a minimum of 6,5 cm² (1 in²). (*See also* D 1817, D 1910 and Tables D 17.4 and D 17.5).

7. The welding of girders, webs, beams and frames to shell and deck in way of end brackets or knees that require continuous welds, should also be continuous.

STAGGERED INTERMITTENT

To be doubled at ends. *See* D 3210

CHAIN INTERMITTENT

SCALLOPED FRAMES, LONGITUDINALS, STIFFENERS, etc., WITH DOUBLE FILLET WELDS

Welding to be carried round the ends of all lugs

See also D 3210 and D 3211

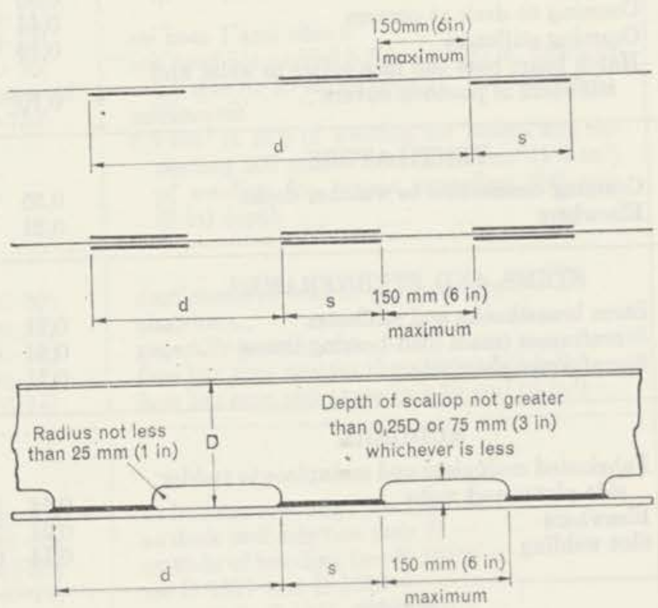


Fig. D 32.1 Weld Types

Section 33

STRUCTURAL DETAILS

3301 Special attention is to be paid to structural continuity. Abrupt changes of shape or section and all sharp corners are to be avoided. The endings of bulwarks, bilge keels or similar attachments to the hull are to be gradually tapered.

3302 For details of openings in strength deck, *see* D 407 to D 409.

3303 Bulwarks, fairlead stools, mouldings and other fittings are not to be welded to the top edge of the sheer-strake within 0,5L amidships. The top edge of the sheer-strake is to be free of all notches and is to be smooth.

3304 Manholes, lightening holes, slots, scallops and notches should be avoided in way of concentrated loads, including high shear loads. In particular, manholes and similar openings should not be cut in vertical or horizontal plate webs in narrow cofferdams within one-third of the length of the webs from each end, nor in floors or double bottom girders close to the toes of bilge or bulkhead brackets unless the stresses in the remaining web plating are calculated and found to be satisfactory. (*See* D 933, D 945 and D 947.)

3305 Where practicable, pillars and bulkheads should be placed in the same vertical line. Beam slots in girders, etc., adjacent to concentrated loads should be collared.

3306 The toes of brackets, etc., should not land on unstiffened panels of plating unless the bracket is well hollowed out and extends close to an adjacent stiffener.

Where large brackets are fitted, sharp angles at their toes should be avoided by making the free edge of the bracket concave or by other means. Special care should be taken to avoid notch effects at the toes of brackets, etc.

3307 The standard of welding and general workmanship of bilge keels, rubbing bars and other similar items attached to highly stressed parts of the ship should be as high as that for the main structural items themselves. The welding of minor items to main structural members is to be avoided where possible.

The ends of bilge keels are to be well sniped and arranged to land in way of an internal stiffener such as a frame, floor or transverse. Such items should be continous over shell butts, the butt being first made flush in way. Ratholes and scallops should be avoided. The butts of bilge keels should be completed before the bilge keels are welded to the shell. (*See* D 517).

3308 The use of backing bars in highly stressed welds is to be avoided where possible. When backing bars are unavoidable, (*e.g.*, in certain rudder designs) special care is to be taken to ensure accurate fit-up. Welding, especially in way of butts of the backing bar, is to be of the highest quality. (*See also* D 2220 for welding of rudders.)

3309 When stiffening members are attached by continuous fillet welds and cross completely finished butt or seam welds, these welds are to be made flush in way of the faying surface. Similarly, for butt welds in webs of stiffening members the butt weld should be completed and generally made flush with the stiffening member before the fillet weld is made.

Where these conditions cannot be complied with, a scallop is to be arranged in the web of the stiffening member. Scallops are to be of such a size, and in such a position, that a satisfactory weld can be made.

3310 Where thick plates are butt welded to thin plates, the edge of the thick plate may require to be tapered. The taper is generally not to exceed 1 in 3.

Where butt welds form a Tee junction, the "leg" of the Tee should, where practicable, be completed (including the back run, if any) before the "table" is welded.

If all three plates are in position when the "leg" of the Tee is welded, steps should be taken to protect the cross plate either by wedging up the two plates adjoining the "leg" of the Tee clear of the cross plate, or else by using a shield of some sort. The "leg" welding should be completed full at the junction and then chipped flush to remove crater cracks, etc.

Where the "leg" is welded before the cross plate is fitted, it is good practice to fit a temporary "run off" plate to allow the Tee "leg" welding to continue past the parent plate edge. When this is done, the run off plate should be clamped in position and not welded unless a trimming edge has been left on the parent plates, in which case the run off plate may be welded to one only of the parent plates.

Where butt welds have been chipped or ground flush to permit fillet welds of abutting members to cross them, care is to be taken to ensure that the ends of the flush portion run out smoothly without notches or sudden change of section.

3311 In higher tensile steel stiffening members particular attention is to be paid to air holes and drain holes. These should be cut clear of the fillet weld wherever this is practicable. Where it is necessary to arrange such holes flush with the attached plating, the holes are to be of elliptical shape.

Section 34

EQUIPMENT

General

3401 The regulations governing the assignment of the figure 1 for equipment are contained in B 201 and B 202.

3402 To entitle a ship to the figure 1, the equipment is to be in accordance with the following requirements and Table D 34.1. For ships engaged on a special or restricted service, an equipment differing from the Table requirements may be approved by the Committee if considered suitable for the particular service on which the ship is to be engaged.

Equipment Number

3403 The equipment of anchors, chain cables, wires and ropes given in Table D 34.1 and associated notes is based on an "Equipment Number" which is to be calculated as follows:—

$$\text{Equipment Number} = \Delta^{\frac{2}{3}} + 2Bh + \frac{A}{10}$$

or in British units:—

$$\text{Equipment Number} = 1{\cdot}012\,\Delta^{\frac{2}{3}} + \frac{Bh}{5{\cdot}382} + \frac{A}{107{\cdot}64}$$

where Δ = moulded displacement, in tonnes (tons), to the summer load waterline,

B = greatest moulded breadth, in metres (feet),

h = effective height, in metres (feet), from the summer load waterline to the top (at side) of the uppermost house having a breadth greater than $B/4$. (*See also* 3404, 3405 and 3406),

A = area, in m² (ft²), in profile view of the hull, within the Rule length of the vessel, and of superstructures and houses above the summer load waterline, which are within the Rule length of the vessel, and also having a width greater than $B/4$. (*See also* 3405 and 3406).

3404 When calculating h, sheer and trim are to be ignored, i.e. h is the sum of the freeboard amidships plus the height (at side) of each tier of houses having a breadth greater than $B/4$.

3405 If a house having a breadth greater than $B/4$ is above a house with a breadth of $B/4$ or less, then the wide house is to be included, but the narrow house ignored.

3406 Screens and bulwarks more than 1,5 m (4·9 ft) in height are to be regarded as parts of houses when determining h and A.

Anchor Weights

3407 The weight per anchor, of bower anchors, given in Table D 34.1 is for anchors of equal weight. The weight of individual anchors may vary by ± 7 per cent of the Table weight provided that the total weight of anchors is not less than would have been required for anchors of equal weight.

3408 The weight of the head, including pins and fittings, of an ordinary stockless anchor is not to be less than 60 per cent of the total weight of the anchor.

3409 When stocked bower or stream anchors are to be used, the weight "ex stock" is to be not less than 80 per cent of the Table weight for ordinary stockless bower anchors. The weight of the stock is to be 25 per cent of the total weight of the anchor, including the shackle, etc., but excluding the stock.

3410 When anchors of a design approved for the designation "High Holding Power Anchor" are used as bower anchors, the weight of each such anchor may be 75 per cent of the Table weight for ordinary stockless bower anchors.

Anchor Design

3411 Anchors are to be of approved design. The design of all anchor heads is to be such as to minimise stress concentrations and, in particular, the radii on all parts of cast anchor heads are to be as large as possible, especially where there is a considerable change of section.

3412 For approval as a "High Holding Power" anchor, satisfactory tests are to be made on various types of bottom, and the anchor is to have a holding power at least twice that of an "Admiralty Standard Stockless" anchor of the same weight.

Chain Cables

3413 Chain cables may be of wrought iron, mild steel, special quality steel or extra special quality steel in accordance with the requirements of P 8.

3414 Chain cables are to be graded as follows (*see also* P 801).

GRADE	MATERIAL	U.T.S. KG/MM² (TON/IN²)
1(a) 1(b) U 1(a)	Wrought iron Mild steel Mild steel	Exceeding 31 (19·7) but not exceeding 41 (26)
U 1(b)	Mild steel	Exceeding 41 (26) but not exceeding 50 (31·7)
U 2(a)	Special Quality steel	Exceeding 50 (31·7) but not exceeding 65 (41·3)
U 2(b)	Special Quality cast steel	Exceeding 50 (31·7) but not exceeding 70 (44·4)
U 3	Extra Special Quality steel	Exceeding 70 (44·4)

3415 Grades 1 (a), 1 (b) or U 1 (a) materials are not to be used in association with high holding power anchors.

Grade U 3 material is only to be used for chain 40 mm ($1\frac{9}{16}$ in) or more in diameter.

3416 When stream anchors are used in association with chain cable, this cable may be either stud link or short link.

3417 The form and proportion of links and shackles are to be in accordance with recognised practice.

Stream Wires, Tow Lines and Mooring Lines

3418 Tow lines and mooring lines may be of wire, natural fibre or synthetic fibre material, or of a mixture of wire and either natural or synthetic fibre. The diameter, construction and specification of wire or natural fibre tow lines and mooring lines are to comply with the requirements of P 9 and P 10.

Where it is proposed to use synthetic fibre ropes the size and construction will be specially considered.

3419 The lengths of individual mooring lines may be reduced by up to 7 per cent of the Table length, provided that the total length of mooring lines is not less than would have resulted had all lines been of equal length.

Testing of Equipment

3420 All anchors and chain cables are to be tested at establishments and on machines recognised by the Committee under the supervision of the Society's Surveyors or other Officer recognised by the Committee, and in accordance with P 7 and P 8.

3421 Test certificates showing particulars of weights of anchors, or size and weight of cable and of the test loads applied are to be furnished. These certificates are to be examined by the Surveyors when the anchors and cables are placed on board the ship.

3422 Steel wire and fibre ropes are to be tested as required by P 9 and P 10.

Arrangements for Working and Stowing Anchors and Cables

3423 A windlass of sufficient power and suitable for the size of chain cable is to be fitted and efficiently bedded and secured to the deck. The thickness of the deck in way of the windlass is to be increased and adequate stiffening is to be provided, to the Surveyor's satisfaction.

3424 An easy lead of the cables from the windlass to the anchors and chain locker is to be arranged.

3425 Hawse pipes are to be of ample thickness and of a suitable size and form to house the anchors efficiently. Substantial chafing lips are to be provided at the shell and deck. The shell plating and framing in way of the hawse pipes are to be reinforced as necessary.

3426 The chain locker is to be of a capacity and depth adequate to provide an easy direct lead for the cable into the chain pipes, when the cable is fully stowed. Chain or spurling pipes are to be of suitable size and provided with chafing lips. The port and starboard cables are to be separated by a division in the locker, and provision is to be made for securing the inboard ends of the cables to the structure.

3427 Satisfactory arrangements are to be made for the stowage and working of the stream anchor if provided.

23rd July, 1970

TABLE D 34.1—EQUIPMENT

Equipment Number (See D 3403)		Equipment Letter	Stockless Bower Anchors		Stockless Stream Anchor	Stud Link Chain Cable for Bower Anchors				Stream Wire or Chain		Tow Line		Mooring Lines		
							Diameter									
Exceeding	Not Exceeding		Number	Weight per Anchor		Total Length	Mild Steel (Grade 1 or U 1)	Special Quality Steel (Grade U 2)	Extra Special Quality Steel (Grade U 3)	Minimum Length	Minimum Breaking Strength	Minimum Length	Minimum Breaking Strength	Number	Minimum Length of each Line	Minimum Breaking Strength
				kg	kg	metres	mm	mm	mm	metres	kg	metres	kg		metres	kg
50	70	A	2	180	60	220	14	12,5	—	80	6600	180	10 000	2	100	3500
70	90	B	2	240	80	220	16	14	—	85	7500	180	10 000	2	100	3750
90	110	C	2	300	100	247,5	17,5	16	—	85	8300	180	10 000	2	110	4000
110	130	D	2	360	120	247,5	19	17,5	—	90	9100	180	10 000	2	110	4500
130	150	E	2	420	140	275	20,5	17,5	—	90	10 000	180	10 000	2	120	5000
150	175	F	2	480	165	275	22	19	—	90	11 000	180	10 000	2	120	5550
175	205	G	2	570	190	302,5	24	20,5	—	90	12 000	180	11 400	2	120	6000
205	240	H	3	660	—	302,5	26	22	—	—	—	180	13 200	2	120	6550
240	280	I	3	780	—	330	28	24	—	—	—	180	15 300	3	120	7250
280	320	J	3	900	—	357,5	30	26	—	—	—	180	17 700	3	140	8000
320	360	K	3	1020	—	357,5	32	28	—	—	—	180	21 100	3	140	8750
360	400	L	3	1140	—	385	34	30	—	—	—	180	22 800	3	140	9500
400	450	M	3	1290	—	385	36	32	—	—	—	180	25 500	3	140	10 250
450	500	N	3	1440	—	412,5	38	34	—	—	—	180	28 200	3	140	11 000
500	550	O	3	1590	—	412,5	40	34	—	—	—	190	31 200	4	160	11 500
550	600	P	3	1740	—	440	42	36	—	—	—	190	34 500	4	160	12 000
600	660	Q	3	1920	—	440	44	38	—	—	—	190	37 800	4	160	12 500
660	720	R	3	2100	—	440	46	40	—	—	—	190	41 400	4	160	13 000
720	780	S	3	2280	—	467,5	48	42	—	—	—	190	45 000	4	170	13 500
780	840	T	3	2460	—	467,5	50	44	—	—	—	190	48 900	4	170	14 000
840	910	U	3	2640	—	467,5	52	46	40	—	—	190	52 800	4	170	14 500
910	980	V	3	2850	—	495	54	48	42	—	—	190	57 000	4	170	15 000
980	1060	W	3	3060	—	495	56	50	44	—	—	200	61 500	4	180	16 000
1060	1140	X	3	3300	—	495	58	50	46	—	—	200	66 000	4	180	17 000
1140	1220	Y	3	3540	—	522,5	60	52	46	—	—	200	70 500	4	180	18 000
1220	1300	Z	3	3780	—	522,5	62	54	48	—	—	200	75 300	4	180	19 000
1300	1390	A†	3	4050	—	522,5	64	56	50	—	—	200	80 100	4	180	20 000
1390	1480	B†	3	4320	—	550	66	58	50	—	—	200	85 200	4	180	21 000
1480	1570	C†	3	4590	—	550	68	60	52	—	—	220	90 600	5	190	22 000
1570	1670	D†	3	4890	—	550	70	62	54	—	—	220	96 000	5	190	23 000
1670	1790	E†	3	5250	—	577,5	73	64	56	—	—	220	104 400	5	190	24 000
1790	1930	F†	3	5610	—	577,5	76	66	58	—	—	220	113 100	5	190	25 000
1930	2080	G†	3	6000	—	577,5	78	68	60	—	—	220	119 100	5	190	26 000
2080	2230	H†	3	6450	—	605	81	70	62	—	—	240	128 400	5	200	27 000
2230	2380	I†	3	6900	—	605	84	73	64	—	—	240	138 300	5	200	28 000
2380	2530	J†	3	7350	—	605	87	76	66	—	—	240	148 200	5	200	29 000
2530	2700	K†	3	7800	—	632,5	90	78	68	—	—	260	150 000	6	200	30 000
2700	2870	L†	3	8300	—	632,5	92	81	70	—	—	260	150 000	6	200	31 000
2870	3040	M†	3	8700	—	632,5	95	84	73	—	—	260	150 000	6	200	32 000
3040	3210	N†	3	9300	—	660	97	84	76	—	—	280	150 000	6	200	33 000
3210	3400	O†	3	9900	—	660	100	87	78	—	—	280	150 000	6	200	34 000
3400	3600	P†	3	10 500	—	660	102	90	78	—	—	280	150 000	6	200	35 000
3600	3800	Q†	3	11 100	—	687,5	105	92	81	—	—	300	150 000	6	200	36 000
3800	4000	R†	3	11 700	—	687,5	107	95	84	—	—	300	150 000	6	200	37 000
4000	4200	S†	3	12 300	—	687,5	111	97	87	—	—	300	150 000	7	200	38 000
4200	4400	T†	3	12 900	—	715	114	100	87	—	—	300	150 000	7	200	39 000
4400	4600	U†	3	13 500	—	715	117	102	90	—	—	300	150 000	7	200	40 000
4600	4800	V†	3	14 100	—	715	120	105	92	—	—	300	150 000	7	200	41 000
4800	5000	W†	3	14 700	—	742,5	122	107	95	—	—	300	150 000	7	200	42 000
5000	5200	X†	3	15 400	—	742,5	124	111	97	—	—	300	150 000	8	200	44 000
5200	5500	Y†	3	16 100	—	742,5	127	111	97	—	—	300	150 000	8	200	46 000
5500	5800	Z†	3	16 900	—	742,5	130	114	100	—	—	300	150 000	8	200	48 000
5800	6100	A*	3	17 800	—	742,5	132	117	102	—	—	300	150 000	8	200	50 000
6100	6500	B*	3	18 800	—	742,5	—	120	107	—	—			9	200	50 000
6500	6900	C*	3	20 000	—	770	—	124	111	—	—	Tow lines not required when ship's length (L) exceeds 180 m.		10	200	50 000
6900	7400	D*	3	21 500	—	770	—	127	114	—	—			11	200	50 000
7400	7900	E*	3	23 000	—	770	—	132	117	—	—			12	200	50 000
7900	8400	F*	3	24 500	—	770	—	137	122	—	—			13	200	50 000
8400	8900	G*	3	26 000	—	770	—	142	127	—	—			14	200	50 000
8900	9400	H*	3	27 500	—	770	—	147	132	—	—			16	200	50 000
9400	10 000	I*	3	29 000	—	770	—	152	132	—	—			18	200	50 000

NOTES—TABLE D 34.1

1. A towline is not required when the length L exceeds 180 m.

2. The rope used for stream wire is to be constructed of not less than 72 wires made up into six strands.

3. Wire ropes used for tow lines and mooring lines are to be of a flexible construction with not less than:—

144 wires in 6 strands with 7 fibre cores for strengths up to 50 000 kg,

222 wires in 6 strands with 1 fibre core for strengths exceeding 50 000 kg.

The wires laid round the fibre centre of each strand are to be made up in not less than two layers.

4. Irrespective of strength requirements, no fibre rope is to be less than 20 mm diameter.

5. For permitted variations in anchor weights, *see* D 3407 and D 3410.

6. Tests. *See* P 7 for anchors.
P 8 for chain cables.
P 9 for wire ropes.
P 10 for fibre ropes.

or in British units :—

TABLE D 34.1—EQUIPMENT

Equipment Number (See D 3403)		Equipment Letter	Stockless Bower Anchors		Stockless Stream Anchor	Stud Link Chain Cables for Bower Anchors				Stream Wire or Chain		Tow Line		Mooring Lines		
						Total Number of 15 Fathom Lengths	Diameter									
Exceeding	Not Exceeding		Number	Weight per Anchor			Mild Steel (Grade 1 or U 1)	Special Quality Steel (Grade U 2)	Extra Special Quality Steel (Grade U 3)	Minimum Length	Minimum Breaking Strength	Minimum Length	Minimum Breaking Strength	Number	Minimum Length of each Line	Minimum Breaking Strength
				cwt	cwt		inches	inches	inches	fms	tons	fms	tons		fms	tons
50	70	A	2	$3\frac{1}{2}$	$1\frac{1}{8}$	8	$\frac{9}{16}$	$\frac{1}{2}$	—	44	6·50	98	9·84	2	55	3·44
70	90	B	2	$4\frac{3}{4}$	$1\frac{5}{8}$	8	$\frac{5}{8}$	$\frac{9}{16}$	—	46	7·38	98	9·84	2	55	3·69
90	110	C	2	$5\frac{7}{8}$	2	9	$\frac{11}{16}$	$\frac{5}{8}$	—	46	8·17	98	9·84	2	60	3·94
110	130	D	2	$7\frac{1}{8}$	$2\frac{3}{8}$	9	$\frac{3}{4}$	$\frac{11}{16}$	—	49	8·96	98	9·84	2	60	4·43
130	150	E	2	$8\frac{1}{4}$	$2\frac{3}{4}$	10	$\frac{13}{16}$	$\frac{11}{16}$	—	49	9·84	98	9·84	2	66	4·92
150	175	F	2	$9\frac{1}{2}$	$3\frac{1}{4}$	10	$\frac{7}{8}$	$\frac{3}{4}$	—	49	10·83	98	9·84	2	66	5·46
175	205	G	2	$11\frac{1}{4}$	$3\frac{3}{4}$	11	$\frac{15}{16}$	$\frac{13}{16}$	—	49	11·81	98	11·22	2	66	5·90
205	240	H	3	13	—	11	1	$\frac{7}{8}$	—	—	—	98	12·99	2	66	6·45
240	280	I	3	$15\frac{3}{8}$	—	12	$1\frac{1}{8}$	$\frac{15}{16}$	—	—	—	98	15·06	3	66	7·13
280	320	J	3	$17\frac{3}{4}$	—	13	$1\frac{3}{16}$	1	—	—	—	98	17·42	3	77	7·87
320	360	K	3	20	—	13	$1\frac{1}{4}$	$1\frac{1}{8}$	—	—	—	98	20·77	3	77	8·61
360	400	L	3	$22\frac{1}{2}$	—	14	$1\frac{5}{16}$	$1\frac{3}{16}$	—	—	—	98	22·44	3	77	9·35
400	450	M	3	$25\frac{3}{8}$	—	14	$1\frac{7}{16}$	$1\frac{1}{4}$	—	—	—	98	25·10	3	77	10·09
450	500	N	3	$28\frac{3}{8}$	—	15	$1\frac{1}{2}$	$1\frac{5}{16}$	—	—	—	98	27·75	3	77	10·83
500	550	O	3	$31\frac{1}{4}$	—	15	$1\frac{9}{16}$	$1\frac{5}{16}$	—	—	—	104	30·71	4	87	11·32
550	600	P	3	$34\frac{1}{4}$	—	16	$1\frac{5}{8}$	$1\frac{7}{16}$	—	—	—	104	33·95	4	87	11·81
600	660	Q	3	$37\frac{3}{4}$	—	16	$1\frac{3}{4}$	$1\frac{1}{2}$	—	—	—	104	37·20	4	87	12·30
660	720	R	3	$41\frac{3}{8}$	—	16	$1\frac{13}{16}$	$1\frac{9}{16}$	—	—	—	104	40·75	4	87	12·79
720	780	S	3	$44\frac{7}{8}$	—	17	$1\frac{7}{8}$	$1\frac{5}{8}$	—	—	—	104	44·29	4	93	13·29
780	840	T	3	$48\frac{1}{2}$	—	17	2	$1\frac{3}{4}$	—	—	—	104	48·13	4	93	13·78
840	910	U	3	52	—	17	$2\frac{1}{16}$	$1\frac{13}{16}$	$1\frac{9}{16}$	—	—	104	51·97	4	93	14·27
910	980	V	3	$56\frac{1}{8}$	—	18	$2\frac{1}{8}$	$1\frac{7}{8}$	$1\frac{5}{8}$	—	—	104	56·10	4	93	14·76
980	1060	W	3	$60\frac{1}{4}$	—	18	$2\frac{3}{16}$	2	$1\frac{3}{4}$	—	—	109	60·53	4	98	15·75
1060	1140	X	3	65	—	18	$2\frac{5}{16}$	2	$1\frac{13}{16}$	—	—	109	64·96	4	98	16·73
1140	1220	Y	3	$69\frac{3}{4}$	—	19	$2\frac{3}{8}$	$2\frac{1}{16}$	$1\frac{13}{16}$	—	—	109	69·39	4	98	17·72
1220	1300	Z	3	$74\frac{3}{8}$	—	19	$2\frac{7}{16}$	$2\frac{1}{8}$	$1\frac{7}{8}$	—	—	109	74·11	4	98	18·70
1300	1390	A†	3	$79\frac{3}{4}$	—	19	$2\frac{1}{2}$	$2\frac{3}{16}$	2	—	—	109	78·83	4	98	19·68
1390	1480	B†	3	85	—	20	$2\frac{5}{8}$	$2\frac{5}{16}$	2	—	—	109	83·95	4	98	20·67
1480	1570	C†	3	$90\frac{3}{8}$	—	20	$2\frac{11}{16}$	$2\frac{3}{8}$	$2\frac{1}{16}$	—	—	120	89·17	5	104	21·65
1570	1670	D†	3	$96\frac{1}{4}$	—	20	$2\frac{3}{4}$	$2\frac{7}{16}$	$2\frac{1}{8}$	—	—	120	94·48	5	104	22·64
1670	1790	E†	3	$103\frac{3}{8}$	—	21	$2\frac{7}{8}$	$2\frac{1}{2}$	$2\frac{3}{16}$	—	—	120	102·75	5	104	23·62
1790	1930	F†	3	$110\frac{1}{2}$	—	21	3	$2\frac{5}{8}$	$2\frac{5}{16}$	—	—	120	111·31	5	104	24·60
1930	2080	G†	3	$118\frac{1}{8}$	—	21	$3\frac{1}{16}$	$2\frac{11}{16}$	$2\frac{3}{8}$	—	—	120	117·22	5	104	25·59
2080	2230	H†	3	127	—	22	$3\frac{3}{16}$	$2\frac{3}{4}$	$2\frac{7}{16}$	—	—	131	126·37	5	109	26·57
2230	2380	I†	3	$135\frac{7}{8}$	—	22	$3\frac{5}{16}$	$2\frac{7}{8}$	$2\frac{1}{2}$	—	—	131	136·11	5	109	27·56
2380	2530	J†	3	$144\frac{3}{4}$	—	22	$3\frac{7}{16}$	3	$2\frac{5}{8}$	—	—	131	145·86	5	109	28·54
2530	2700	K†	3	$153\frac{5}{8}$	—	23	$3\frac{9}{16}$	$3\frac{1}{16}$	$2\frac{11}{16}$	—	—	142	147·63	6	109	29·53
2700	2870	L†	3	$163\frac{1}{2}$	—	23	$3\frac{5}{8}$	$3\frac{3}{16}$	$2\frac{3}{4}$	—	—	142	147·63	6	109	30·51
2870	3040	M†	3	$171\frac{3}{8}$	—	23	$3\frac{3}{4}$	$3\frac{5}{16}$	$2\frac{7}{8}$	—	—	142	147·63	6	109	31·49
3040	3210	N†	3	$183\frac{1}{8}$	—	24	$3\frac{13}{16}$	$3\frac{5}{16}$	3	—	—	153	147·63	6	109	32·48
3210	3400	O†	3	195	—	24	$3\frac{15}{16}$	$3\frac{7}{16}$	$3\frac{1}{16}$	—	—	153	147·63	6	109	33·46
3400	3600	P†	3	$206\frac{3}{4}$	—	24	4	$3\frac{9}{16}$	$3\frac{1}{16}$	—	—	153	147·63	6	109	34·45
3600	3800	Q†	3	$218\frac{5}{8}$	—	25	$4\frac{1}{8}$	$3\frac{5}{8}$	$3\frac{3}{16}$	—	—	164	147·63	6	109	35·43
3800	4000	R†	3	$230\frac{3}{8}$	—	25	$4\frac{3}{16}$	$3\frac{3}{4}$	$3\frac{5}{16}$	—	—	164	147·63	6	109	36·42
4000	4200	S†	3	$242\frac{1}{4}$	—	25	$4\frac{3}{8}$	$3\frac{13}{16}$	$3\frac{7}{16}$	—	—	164	147·63	7	109	37·40
4200	4400	T†	3	254	—	26	$4\frac{1}{2}$	$3\frac{15}{16}$	$3\frac{7}{16}$	—	—	164	147·63	7	109	38·38
4400	4600	U†	3	$265\frac{7}{8}$	—	26	$4\frac{5}{8}$	4	$3\frac{9}{16}$	—	—	164	147·63	7	109	39·37
4600	4800	V†	3	$277\frac{5}{8}$	—	26	$4\frac{3}{4}$	$4\frac{1}{8}$	$3\frac{5}{8}$	—	—	164	147·63	7	109	40·35
4800	5000	W†	3	$289\frac{1}{2}$	—	27	$4\frac{13}{16}$	$4\frac{3}{16}$	$3\frac{3}{4}$	—	—	164	147·63	7	109	41·34
5000	5200	X†	3	$303\frac{3}{8}$	—	27	$4\frac{7}{8}$	$4\frac{3}{8}$	$3\frac{13}{16}$	—	—	164	147·63	8	109	43·30
5200	5500	Y†	3	$317\frac{1}{8}$	—	27	5	$4\frac{3}{8}$	$3\frac{13}{16}$	—	—	164	147·63	8	109	45·27
5500	5800	Z†	3	$332\frac{7}{8}$	—	27	$5\frac{1}{8}$	$4\frac{1}{2}$	$3\frac{15}{16}$	—	—	164	147·63	8	109	47·24
5800	6100	A*	3	$350\frac{1}{2}$	—	27	$5\frac{3}{16}$	$4\frac{5}{8}$	4	—	—	164	147·63	8	109	49·20
6100	6500	B*	3	$370\frac{1}{4}$	—	27	—	$4\frac{3}{4}$	$4\frac{3}{16}$	—	—	Tow lines not required when ship's length (L) exceeds 590 ft		9	109	49·20
6500	6900	C*	3	$393\frac{7}{8}$	—	28	—	$4\frac{7}{8}$	$4\frac{3}{8}$	—	—			10	109	49·20
6900	7400	D*	3	$423\frac{3}{8}$	—	28	—	5	$4\frac{1}{2}$	—	—			11	109	49·20
7400	7900	E*	3	453	—	28	—	$5\frac{3}{16}$	$4\frac{5}{8}$	—	—			12	109	49·20
7900	8400	F*	3	$482\frac{1}{2}$	—	28	—	$5\frac{3}{8}$	$4\frac{13}{16}$	—	—			13	109	49·20
8400	8900	G*	3	512	—	28	—	$5\frac{9}{16}$	5	—	—			14	109	49·20
8900	9400	H*	3	$541\frac{5}{8}$	—	28	—	$5\frac{3}{4}$	$5\frac{3}{16}$	—	—			16	109	49·20
9400	10 000	I*	3	$571\frac{1}{8}$	—	28	—	6	$5\frac{3}{16}$	—	—			18	109	49·20

NOTES—TABLE D 34.1

1. A towline is not required when the length L exceeds 590 ft.

2. The rope used for stream wire is to be constructed of not less than 72 wires made up into six strands.

3. Wire ropes used for tow lines and mooring lines are to be of a flexible construction with not less than:—

   144 wires in 6 strands with 7 fibre cores for strengths up to 49·21 tons,

   222 wires in 6 strands with 1 fibre core for strengths exceeding 49·21 tons.

   The wires laid round the fibre centre of each strand are to be made up in not less than two layers.

4. Irrespective of strength requirements, no fibre rope is to be less than 2·47 inches circumference.

5. For permitted variations in anchor weights, *see* D 3407 and D 3410.

6. TESTS. *See* P 7 for anchors.
   P 8 for chain cables.
   P 9 for wire ropes.
   P 10 for fibre ropes.

TABLE D 34.2

RENEWAL OF STEERING CHAINS AND CHAIN CABLES WHEN WORN

When any length of a chain is so worn that the mean diameter at its most worn part is reduced to the size given in the following Table it is to be renewed.

ORIGINAL DIAMETER	MEAN DIAMETER REQUIRING RENEWAL	ORIGINAL DIAMETER	MEAN DIAMETER REQUIRING RENEWAL	ORIGINAL DIAMETER	MEAN DIAMETER REQUIRING RENEWAL	ORIGINAL DIAMETER	MEAN DIAMETER REQUIRING RENEWAL
mm	mm	mm	mm	mm	mm	mm	mm
16	14,5	35	31	54	48,5	73	65
17	15,5	36	32	55	49,5	74	66
18	16	37	33	56	50	75	67
19	17	38	34	57	51	76	68
20	18	39	35	58	51,5	77	69
21	18,5	40	36	59	52,5	78	70
22	19,5	41	36,5	60	53,5	79	71
23	20,5	42	37,5	61	54,5	80	72
24	21,5	43	38,5	62	55,5	81	73
25	22,5	44	39,5	63	56,5	82	74
26	23	45	40	64	57,5	83	75
27	24	46	41	65	58	84	75,5
28	25	47	42	66	59	85	76
29	26	48	43	67	60	86	77
30	27	49	43,5	68	61	87	77,5
31	28	50	44,5	69	62	88	78,5
32	28,5	51	45,5	70	63	89	79,5
33	29,5	52	46,5	71	64		
34	30,5	53	47,5	72	64,5		

or in British units:—

TABLE D 34.2

RENEWAL OF STEERING CHAINS AND CHAIN CABLES WHEN WORN

When any length of a chain is so worn that the mean diameter at its most worn part is reduced to the size given in the following Table it is to be renewed.

ORIGINAL DIAMETER	MEAN DIAMETER REQUIRING RENEWAL	ORIGINAL DIAMETER	MEAN DIAMETER REQUIRING RENEWAL	ORIGINAL DIAMETER	MEAN DIAMETER REQUIRING RENEWAL	ORIGINAL DIAMETER	MEAN DIAMETER REQUIRING RENEWAL
Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches
$\frac{3}{8}$	$\frac{11}{32}$	$1\frac{5}{16}$	$1\frac{3}{16}$	$2\frac{1}{4}$	2	$3\frac{3}{16}$	$2\frac{7}{8}$
$\frac{7}{16}$	$\frac{13}{32}$	$1\frac{3}{8}$	$1\frac{7}{32}$	$2\frac{5}{16}$	$2\frac{1}{16}$	$3\frac{1}{4}$	$2\frac{15}{16}$
$\frac{1}{2}$	$\frac{7}{16}$	$1\frac{7}{16}$	$1\frac{9}{32}$	$2\frac{3}{8}$	$2\frac{1}{8}$	$3\frac{5}{16}$	$2\frac{31}{32}$
$\frac{9}{16}$	$\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{11}{32}$	$2\frac{7}{16}$	$2\frac{3}{16}$	$3\frac{3}{8}$	$3\frac{1}{32}$
$\frac{5}{8}$	$\frac{9}{16}$	$1\frac{9}{16}$	$1\frac{13}{32}$	$2\frac{1}{2}$	$2\frac{1}{4}$	$3\frac{7}{16}$	$3\frac{1}{16}$
$\frac{11}{16}$	$\frac{5}{8}$	$1\frac{5}{8}$	$1\frac{15}{32}$	$2\frac{9}{16}$	$2\frac{9}{32}$	$3\frac{1}{2}$	$3\frac{1}{8}$
$\frac{3}{4}$	$\frac{21}{32}$	$1\frac{11}{16}$	$1\frac{1}{2}$	$2\frac{5}{8}$	$2\frac{11}{32}$	$3\frac{9}{16}$	$3\frac{3}{16}$
$\frac{13}{16}$	$\frac{23}{32}$	$1\frac{3}{4}$	$1\frac{9}{16}$	$2\frac{11}{16}$	$2\frac{13}{32}$	$3\frac{5}{8}$	$3\frac{1}{4}$
$\frac{7}{8}$	$\frac{25}{32}$	$1\frac{13}{16}$	$1\frac{5}{8}$	$2\frac{3}{4}$	$2\frac{15}{32}$	$3\frac{11}{16}$	$3\frac{5}{16}$
$\frac{15}{16}$	$\frac{27}{32}$	$1\frac{7}{8}$	$1\frac{11}{16}$	$2\frac{13}{16}$	$2\frac{17}{32}$	$3\frac{3}{4}$	$3\frac{3}{8}$
1	$\frac{29}{32}$	$1\frac{15}{16}$	$1\frac{23}{32}$	$2\frac{7}{8}$	$2\frac{9}{16}$	$3\frac{13}{16}$	$3\frac{7}{16}$
$1\frac{1}{16}$	$\frac{15}{16}$	2	$1\frac{25}{32}$	$2\frac{15}{16}$	$2\frac{5}{8}$	$3\frac{7}{8}$	$3\frac{1}{2}$
$1\frac{1}{8}$	1	$2\frac{1}{16}$	$1\frac{27}{32}$	3	$2\frac{11}{16}$		
$1\frac{3}{16}$	$1\frac{1}{16}$	$2\frac{1}{8}$	$1\frac{29}{32}$	$3\frac{1}{16}$	$2\frac{3}{4}$		
$1\frac{1}{4}$	$1\frac{1}{8}$	$2\frac{3}{16}$	$1\frac{31}{32}$	$3\frac{1}{8}$	$2\frac{13}{16}$		

OIL TANKERS

Section 40

GENERAL

Application

4001 The following Rules apply to the Class 100A1 Oil Tanker. (*See* B 103.) The scantlings and arrangements of tankers intended for cargoes other than petroleum will be specially considered in relation to the nature and density of the cargo.

Sections D 1 to D 34 apply to tankers except as otherwise required by the following Rules.

For scantling reductions when higher tensile steel complying with P 3 is used, *see* D 65, D 66 and D 67.

Method of Construction

4002 The following Rules and Tables give requirements for welded construction with certain modifications when riveting is adopted.

Structural Design

4003 The Rules apply to single deck tankers over 90 m (295 ft) in length with machinery aft and having two or more longitudinal bulkheads.

The bottom and deck are to be framed longitudinally in the cargo tank spaces; the Rules assume longitudinal framing at the sides and longitudinal bulkheads where the length of the ship exceeds 200 m (656 ft), but alternative designs will be considered.

If the proportion of length to depth exceeds sixteen or the ratio of breadth to depth exceeds 2:1, increased scantlings may be required.

4004 The length of a tank is not to exceed 0,2L. When the length exceeds 0,1L or 15 m (49 ft), whichever is the greater, a transverse wash bulkhead is to be fitted at about the mid-length of the tank.

4005 The scantlings of primary supporting structure such as transverses, girders, webs and stringers may be assessed using direct calculation. In such cases the calculations are to be submitted for approval.

Loading

4006 Any dry tanks, or tanks intended for water ballast only and thus empty in the loaded condition, are to be indicated on the plans submitted for approval and the arrangements are to be such that these tanks cannot be used for any other purpose.

4007 In order to guard against high stresses being imposed through an unsatisfactory cargo or ballast loading it is recommended that tankers be supplied with an approved instrument for determining suitable loading.

Quality of Material

4008 Where the thickness of plating exceeds 20,5 mm (0·80 in) and the seams and butts are welded, steel of grade D (*see* Table P 2.2), will generally be required for the following parts of the structure:—

(*a*) Sheerstrake, strength deck stringer and plating, top strake of the longitudinal bulkhead, deck longitudinals of the slab type where cut from plates and through brackets for deck longitudinals.

This grade D plating is to extend from 0,15L aft of amidships to 0,15L forward of amidships where the length is 155 m (508 ft) and below, and from 0,2L aft of amidships to 0,2L forward of amidships where the length is 215 m (705 ft) and above, with intermediate values obtained by interpolation, always provided that the forward limit extends at least 3 m (10 ft) forward of the bridge front.

In addition, the sheerstrake and strength deck stringer and plating are to be of grade D in way of the poop front, extending forward to cover any pump room openings. Any stringer, deck or sheerstrake plating between the above after limit of the midship portion and 0,25L aft of amidships which is above 25,5 mm (1·00 in) in thickness should also be of grade D.

Any sheerstrake or stringer plate outside the above limits which exceeds 25,5 mm (1·00 in) in thickness should also be grade D.

Face flats of deck longitudinals or girders are to be of grade D if exceeding 35,5 mm (1·40 in) in thickness.

(*b*) Bottom shell plating to upper turn of bilge, bottom strake of the longitudinal bulkhead, bottom longitudinals of the slab type cut from plates and through brackets of bottom longitudinals.

This grade D plating is to extend from 0,15L aft of amidships to 0,15L forward of amidships where the length is 155 m (508 ft) and below, and from 0,2L aft of amidships to 0,2L forward of amidships where the length is 215 m (705 ft) and above with intermediate values obtained by interpolation.

In addition, the bottom plating between the above after limit and 0,25L aft of amidships is to be of grade D where the thickness is above 25,5 mm (1·00 in).

Where the bottom plating is required to be of steel of the above grade, the keel plate is also to be of the same grade.

Face flats of bottom longitudinals or girders are to be of grade D if exceeding 35,5 mm (1·40 in) in thickness.

4009 Strakes of grade E steel are to be arranged as in Table D 40.1.

TABLE D 40.1

LENGTH L		Grade E Strakes
Over	Not exceeding	
Metres (Feet)	Metres (Feet)	
215 (705)	230 (754)	Bilge strake
230 (754)	245 (803)	Bilge strake Sheerstrake
245 (803)	260 (852)	Bilge strake Sheerstrake Bottom strake in way of longitudinal bulkhead
260 (852)		As for tankers over 245 m (803 ft) with the addition of the keel The deck strake in way of the longitudinal bulkhead is also to be grade E unless the top strake of the bulkhead is grade D

The fore and aft extent of the grade E strakes is to be as follows:—

(a) Sheerstrake and deck plating from within the poop to 0,2L forward of amidships.

(b) Bottom and bilge plating from 0,2L aft of amidships to 0,2L forward of amidships.

The breadth of each strake is not to be less than 1525 mm (60 in), except that the bilge strake shall not be less than 1835 mm (72 in).

Any plates in the deck or bottom exceeding 35,5 mm (1·40 in) in thickness are to be grade E.

The use of riveted seams as an alternative to strakes of grade E steel will be specially considered.

Cofferdams and Below Deck Passages or Tunnels

4010 Cofferdams are to be provided at the forward and after ends of the oil cargo spaces; cofferdams are to be at least 760 mm (30 in) in length and are to cover the whole area of the end bulkheads of the cargo spaces.

Pump rooms or water ballast tanks will be accepted in lieu of a cofferdam. An oil fuel bunker will also be accepted provided the bulkhead between it and the cargo tank is completely welded.

(The attention of the Owners should be drawn to the Suez Canal Authorities' requirement that only pump rooms or water ballast tanks can be accepted in lieu of a cofferdam.)

A cofferdam is also to be arranged between a cargo oil tank and accommodation spaces or between a cargo oil tank and spaces containing electrical equipment other than spaces where the only electrical equipment is lighting fittings complying with M 1604. (*See also* M 1605.) Where the bridge 'tween deck acts as a cofferdam any access to this 'tween deck from the deck above is to be from the open deck.

Passages or tunnels passing through, or adjacent to, a cargo oil tank and not separated from it by a cofferdam are to be provided with mechanical ventilation, and any access is to be from the open deck.

Freeing Arrangements and Gangway

4011 Ships with bulwarks are to have open rails fitted for at least half the length of the exposed part of each well.

A strong permanent fore and aft gangway is to be fitted at the level of the superstructure decks. Where there is no accommodation forward, the gangway between the bridge and forecastle may be omitted and where there is no midship erection and all accommodation, etc., is aft, the gangway may be omitted entirely. Arrangements are, however, to be made to give safe access to the fore end of the ship.

Submission of Plans

4012 In addition to the plans required by D 109, plans showing the construction of the transverse and longitudinal oiltight bulkheads, end connections for all longitudinals and other framing members, the structure at the ends of the ship, deckhouses protecting machinery casings and arrangements at the junction of transverse and longitudinal framing are also to be submitted.

A plan showing the arrangement and sequence of erection of the fabrication units is to be submitted.

4013 The information required by D 41 is to be forwarded when the midship section is submitted.

Anodes in Tanks

4014 When anodes are fitted in tanks they are to be of approved design and securely attached to the structure, both initially and during service. A plan showing the details of design and attachment and the location of the anodes is to be submitted.

Magnesium anodes are only permitted in tanks intended solely for water ballast.

Fittings in Tanks

4015 Ladders, pipe hangers and other fittings in the cargo tanks and pump rooms are to be securely fastened to the structure.

Corrosion Control

4016 When an approved system of corrosion control is installed the reduction in thickness given in Table D 40.2 will be allowed. Where reductions are desired at the top of the tank within 1,525 m (5 ft) of the deck at side, this part of the tank is to be coated but other approved systems may be used for the remainder of the tank.

When reductions have been effected a notation will be made in the Register Book.

TABLE D 40.2

ITEM	PERMISSIBLE REDUCTION IN THICKNESS
Plating and stiffeners of transverse and longitudinal bulkheads. Bottom, side and deck transverses. Transverse side framing. Vertical webs and horizontal girders. Cross ties.	10 per cent
Keel. Bottom and side shell. Deck plating. Bottom, side and deck longitudinals. Bottom and deck centreline and side girders.	5 per cent

The minimum thickness of keel, bottom and deck plating given in D 4303, D 4302 and D 4202 respectively may be reduced by 5 per cent. The minimum thickness of the remaining items may be 1,0 mm (0·04 in) less than the minimum given in D 5309.

Special consideration will be given to the extent of protection required in tankers intended solely for the carriage of crude oil.

The plans of midship section, profile and decks and shell expansion should indicate both the rule scantlings and the thicknesses proposed.

Section 41

LONGITUDINAL STRENGTH

4101 The section modulus is not to be less than the greater of the following values:—

(a) M cm³ (in²ft)

(b) $\dfrac{M}{3} + 104\ \text{SWBM}$ cm³ $\left(\dfrac{M}{3} + \dfrac{\text{SWBM}}{6\cdot1}\ \text{in}^2\text{ft}\right)$

where $M = f\,K\,B\,(C_b + 0{,}70) \times 10^5$ cm³

$(M = f\,K\,B\,(C_b + 0\cdot70) \times 10^3$ in² ft)

f is as follows:—

Length L	f	
	Deck	Keel
up to 100 m (328 ft)	0,93	0,96
300 m (984 ft) and above	0,90	0,90

Intermediate values to be determined by interpolation

K is to be determined from Table D 41.1,

C_b is the moulded block coefficient at load draught. Where the block coefficient is less than 0,75, a value equal to $\left(\dfrac{C_b + 0{,}75}{2}\right)$ is to be used. The block coefficient is to be determined using the length L as defined in D 201,

B is the moulded breadth, in metres (feet),

SWBM is the maximum still water bending moment, in tonnes metres (tons feet), hogging or sagging (*see* 4103 and 4104).

NOTES

1. When the required section modulus is the minimum acceptable, i.e. that given by (a) above, the maximum associated still water bending moment will be 6,4 (keel modulus) $\times 10^{-3}$ tonne m (4·08 (keel modulus) ton ft) which corresponds to a stress of 6,4 kg/mm² (4·08 ton/in²).

2. The section modulus calculated by (b) above should be based upon the f value for the keel.
The deck modulus/keel modulus ratio should be the same as the ratio of the f values appropriate to the length.

4102 The midship deck and bottom areas may be determined from Table D 41.2 and Notes. The area derived from the Table and Notes is the bottom area. The deck area is to be 95 per cent of the corrected bottom area.

Alternatively, a direct calculation of section modulus may be carried out (*see* 4106).

4103 The still water bending moment is to be calculated for the homogeneous loaded condition (excluding dry tanks and tanks used solely for water ballast) and for the ballast or part loaded conditions (departure and arrival). The calculations are to be submitted.

4104 Where in loaded, ballast or part loaded conditions the load is not uniformly distributed over the cargo tank length, curves of still water bending moment and shear force are to be submitted. The method of calculating these curves is to be submitted together with the assumed longitudinal distribution of lightship weight.

4105 When the still water bending moment is required to be calculated for conditions other than homogeneous load conditions, the approved loading is to be incorporated in the Loading Manual.

4106 Where a direct calculation of midship section modulus is carried out all continuous longitudinal material is to be included in the calculation of the inertia of the section, and the lever "y" is to be measured from the neutral axis to the top of the keel and to the moulded deck line at side (see also Note 4 to Table D 41.2).

The section modulus calculation is to be forwarded with the midship section.

TABLE D 41.1—VALUES OF K

LENGTH L	K	Difference in K per 5 m difference in L	LENGTH L	K	Difference in K per 5 m difference in L	LENGTH L	K	Difference in K per 5 m difference in L
Metres			Metres			Metres		
					0,255			0,380
90	0,747		**195**	4,329		**300**	11,437	
		0,118			0,265			0,385
95	0,865		**200**	4,594		**305**	11,822	
		0,120			0,274			0,391
100	0,985		**205**	4,868		**310**	12,213	
		0,121			0,282			0,397
105	1,106		**210**	5,150		**315**	12,610	
		0,122			0,290			0,403
110	1,228		**215**	5,440		**320**	13,013	
		0,123			0,299			0,410
115	1,351		**220**	5,739		**325**	13,423	
		0,125			0,308			0,416
120	1,476		**225**	6,047		**330**	13,839	
		0,130			0,317			0,423
125	1,606		**230**	6,364		**335**	14,262	
		0,138			0,326			0,429
130	1,744		**235**	6,690		**340**	14,691	
		0,147			0,335			0,435
135	1,891		**240**	7,025		**345**	15,126	
		0,155			0,344			0,442
140	2,046		**245**	7,369		**350**	15,568	
		0,164			0,353			0,448
145	2,210		**250**	7,722		**355**	16,016	
		0,172			0,361			0,454
150	2,382		**255**	8,083		**360**	16,470	
		0,181			0,365			0,461
155	2,563		**260**	8,448		**365**	16,931	
		0,189			0,368			0,467
160	2,752		**265**	8,816		**370**	17,398	
		0,198			0,370			0,473
165	2,950		**270**	9,186		**375**	17,871	
		0,207			0,372			0,480
170	3,157		**275**	9,558		**380**	18,351	
		0,215			0,373			0,486
175	3,372		**280**	9,931		**385**	18,837	
		0,224			0,374			0,492
180	3,596		**285**	10,305		**390**	19,339	
		0,234			0,375			0,499
185	3,830		**290**	10,680		**395**	19,828	
		0,244			0,377			0,505
190	4,074		**295**	11,057		**400**	20,333	
		0,255			0,380			

or in British units:—

TABLE D 41.1—VALUES OF K

LENGTH L	K	Difference in K per 1 ft difference in L	LENGTH L	K	Difference in K per 1 ft difference in L	LENGTH L	K	Difference in K per 1 ft difference in L
Feet			Feet		0·0024	Feet		0·0036
300	0·121		640	0·672		980	1·757	
		0·0011			0·0025			0·0036
310	0·132		650	0·697		990	1·793	
		0·0011			0·0026			0·0037
320	0·143		660	0·723		1000	1·830	
		0·0011			0·0026			0·0037
330	0·154		670	0·749		1010	1·867	
		0·0011			0·0027			0·0037
340	0·165		680	0·776		1020	1·904	
		0·0012			0·0027			0·0037
350	0·177		690	0·803		1030	1·941	
		0·0012			0·0028			0·0038
360	0·189		700	0·831		1040	1·979	
		0·0012			0·0028			0·0038
370	0·201		710	0·859		1050	2·017	
		0·0012			0·0028			0·0039
380	0·213		720	0·887		1060	2·056	
		0·0012			0·0029			0·0039
390	0·225		730	0·916		1070	2·095	
		0·0012			0·0029			0·0039
400	0·237		740	0·945		1080	2·134	
		0·0012			0·0030			0·0040
410	0·249		750	0·975		1090	2·174	
		0·0013			0·0030			0·0040
420	0·262		760	1·005		1100	2·214	
		0·0013			0·0031			0·0040
430	0·275		770	1·036		1110	2·254	
		0·0014			0·0031			0·0041
440	0·289		780	1·067		1120	2·295	
		0·0014			0·0032			0·0041
450	0·303		790	1·099		1130	2·336	
		0·0015			0·0032			0·0042
460	0·318		800	1·131		1140	2·378	
		0·0016			0·0033			0·0042
470	0·334		810	1·164		1150	2·420	
		0·0016			0·0033			0·0042
480	0·350		820	1·197		1160	2·462	
		0·0016			0·0034			0·0043
490	0·366		830	1·231		1170	2·505	
		0·0017			0·0034			0·0043
500	0·383		840	1·265		1180	2·548	
		0·0017			0·0034			0·0043
510	0·400		850	1·299		1190	2·591	
		0·0018			0·0035			0·0044
520	0·418		860	1·334		1200	2·635	
		0·0019			0·0035			0·0044
530	0·437		870	1·369		1210	2·679	
		0·0019			0·0035			0·0044
540	0·456		880	1·404		1220	2·723	
		0·0020			0·0035			0·0045
550	0·476		890	1·439		1230	2·768	
		0·0020			0·0035			0·0045
560	0·496		900	1·474		1240	2·813	
		0·0020			0·0035			0·0046
570	0·516		910	1·509		1250	2·859	
		0·0021			0·0035			0·0046
580	0·537		920	1·544		1260	2·905	
		0·0021			0·0035			0·0046
590	0·558		930	1·579		1270	2·951	
		0·0022			0·0035			0·0047
600	0·580		940	1·614		1280	2·998	
		0·0022			0·0035			0·0047
610	0·602		950	1·649		1290	3·045	
		0·0023			0·0036			0·0047
620	0·625		960	1·685		1300	3·092	
		0·0023			0·0036			0·0048
630	0·648		970	1·721		1310	3·140	
		0·0024			0·0036			

TABLE D 41.2—BASIC BOTTOM AREA

REQUIRED KEEL MODULUS	BASIC AREA	BASIC DEPTH D_1	DEPTH CORRECTION
1	2	3	4
cm^3	cm^2	metres	cm^2
1×10^6	870	5,70	130
2×10^6	1305	7,30	150
3×10^6	1665	8,50	170
4×10^6	2000	9,45	185
6×10^6	2590	10,75	210
8×10^6	3145	11,80	225
10×10^6	3675	12,55	255
14×10^6	4665	13,75	295
18×10^6	5585	14,70	330
23×10^6	6700	15,65	370
29×10^6	8010	16,65	410
37×10^6	9630	17,85	470
47×10^6	11 540	19,00	530
57×10^6	13 420	19,95	590
71×10^6	15 860	21,20	675
85×10^6	18 280	22,10	750

NOTES.—TABLE D 41.2

1. Where the depth D is greater/less than the basic depth D_1 the tabular bottom area is to be reduced/increased at the rate per metre of difference given in column 4.

2. The bottom area is that for one side of the ship and includes the following items up to 0,1D from the base line:—
   - One half the keel plate
   - Bottom and bilge plating
   - Bottom, bilge and side longitudinals
   - One half the centre girder
   - Side girders
   - Plating and longitudinal stiffeners of longitudinal bulkheads (including one half of a centre line bulkhead).

3. The deck area is that for one side of the ship in way of openings and includes the following items down to 0,1D from the deck line at side:—
   - Deck stringer and plating
   - Sheerstrake
   - Stringer angle (if fitted)
   - Deck and side longitudinals
   - One half the centre line deck girder
   - Side girders
   - Plating and longitudinal stiffeners of longitudinal bulkheads (including one half of a centre line bulkhead).

4. Elliptical deck openings need not be deducted provided their major axes are fore and aft, the ratio of the length to breadth of each opening is not less than 2:1 and the total breadth of such openings in a transverse section does not exceed 0,06B.

   Lightening holes in girders need not be deducted provided their depth does not exceed 20 per cent of the depth of the girder web.

   Where longitudinals are scalloped the net area in way of scallop is to be used. Isolated drain holes need not be deducted, but compensation will be required for large drain holes at the bulkheads.

5. For permissible reductions when an approved system of corrosion control is fitted, *see* D 4016.

or in British units:—

TABLE D 41.2—BASIC BOTTOM AREA

REQUIRED KEEL MODULUS	BASIC AREA	BASIC DEPTH D_1	DEPTH CORRECTION
1	2	3	4
In² ft 5000	In² 133	Feet 18·5	In² 6
10 000	202	23·5	7
15 000	252	28·0	8
20 000	305	31·0	9
30 000	400	35·0	10
40 000	481	38·5	11
50 000	565	41·0	12
70 000	713	45·0	14
90 000	855	48·0	15
120 000	1054	52·0	18
150 000	1256	55·0	20
190 000	1508	58·5	22
240 000	1793	62·5	25
290 000	2081	65·5	28
360 000	2451	69·5	32
430 000	2820	72·5	35

NOTES.—TABLE D 41.2

1. Where the depth D is greater/less than the basic depth D_1 the tabular bottom area is to be reduced/increased at the rate per foot of difference given in column 4.

2. The bottom area is that for one side of the ship and includes the following items up to 0·1D from the base line:—
   - One half the keel plate
   - Bottom and bilge plating
   - Bottom, bilge and side longitudinals
   - One half the centre girder
   - Side girders
   - Plating and longitudinal stiffeners of longitudinal bulkheads (including one half of a centre line bulkhead)

3. The deck area is that for one side of the ship in way of openings and includes the following items down to 0·1D from the deck line at side:—
   - Deck stringer and plating
   - Sheerstrake
   - Stringer angle (if fitted)
   - Deck and side longitudinals
   - One half the centre line deck girder
   - Side girders
   - Plating and longitudinal stiffeners of longitudinal bulkheads (including one half of a centre line bulkhead)

4. Elliptical deck openings need not be deducted provided their major axes are fore and aft, the ratio of the length to breadth of each opening is not less than 2:1 and the total breadth of such openings in a transverse section does not exceed 0·06B.

Lightening holes in girders need not be deducted provided their depth does not exceed 20 per cent of the depth of the girder web.

Where longitudinals are scalloped the net area in way of scallop is to be used. Isolated drain holes need not be deducted, but compensation will be required for large drain holes at the bulkheads.

5. For permissible reductions when an approved system of corrosion control is fitted, *see* D 4016.

DECKS

Symbols

4201

L = length of ship, in metres (feet),

L_1 = length of ship, in metres (feet), but need not be taken as greater than 215 m (705 ft),

B = moulded breadth, in metres (feet),

d = moulded draught, in metres (feet), but is not to be taken as less than 0,05L,

s = spacing of longitudinals, in mm (in).

Strength Deck

4202 The thickness of deck plating amidships is to be that necessary to give the section modulus required by D 4101, but is not to be less than:—

$$t = \frac{s}{3570}\left(L_1 + 75\right)\sqrt{\frac{d}{L_1}} \text{ mm}$$

$$\left(t = \frac{s}{11{\cdot}7}\left(\frac{L_1 + 246}{1000}\right)\sqrt{\frac{d}{L_1}} \text{ in}\right)$$

The midship thickness is to be maintained from 0,2L aft of amidships to 0,2L forward of amidships and is to be gradually tapered to the end thickness. The midship thickness may be required over an increased extent if shown to be necessary by the bending moment curves.

4203 The thickness at the poop front is to extend into the poop for a distance at least equal to one-third the breadth B.

Where the machinery opening extends forward beyond a point one-third of the breadth B abaft the poop front, and the width of the casing exceeds one-half the breadth of the ship at the poop front, the thickness of deck plating may require to be increased. The forward corners of the casing opening are to be well rounded.

4204 The thickness of the stringer plate at the ends of the bridge is to be increased by 20 per cent.

If the poop front extends within 0,25L from amidships the stringer plate at the break is to be increased by 20 per cent. No increase is required if the poop front is 0,3L from amidships or greater. The increase at intermediate lengths is to be obtained by interpolation and is to be applied to the tapered thickness of the stringer plate.

The increase in thickness need not exceed 5 mm (0·20 in).

End Thickness

4205 The thickness of the deck stringer and plating for 0,05L at the fore end and 0,1L at the aft end is not to be less than $6{,}0 + \frac{L}{48}$ mm $\left(0{\cdot}235 + \frac{L}{4000} \text{ in}\right)$

4206 If a stringer angle is fitted, in way of the cargo tanks and for at least one-third of the breadth B within the poop, it is to have 150 mm (6 in) flanges when the length L does not exceed 137 m (450 ft), 180 mm (7 in), flanges for lengths exceeding 137 m (450 ft) and not exceeding 167,5 m (550 ft) and 200 mm (8 in) flanges above 170 m (560 ft). The thickness is to be that of the sheerstrake or stringer whichever is less. Alternative riveted connections will be specially considered.

If the stringer angle is cut at the scuppers, compensation is to be provided. (*See also* D 4311).

4207 Where a rounded sheerstrake is incorporated the radius should, in general, not be less than 15 times the thickness. The radius should be made by careful cold rolling or bending. Where grade E plates are subjected to severe cold working or where local heating of the plates is adopted, the plates may require to be re-normalised.

4208 The corners of all deck openings are to be well rounded and smooth, and strength is to be maintained in way of pump room entrances or other openings but compensation will not, in general, be required for small elliptical openings (*see* Note 4 to Table D 41.2) nor forward of 0,2L forward of amidships nor abaft the poop front bulkhead. It is recommended that compensation for deck openings should be in the form of an increased thickness of plating, but alternative methods will be specially considered.

Lower Decks

4209 The scantlings and arrangements of lower decks are to be as required by D 4, D 6, D 8, D 13 and D 14.

4210 Abrupt discontinuities at the ends of lower decks and flats are to be avoided by suitable tapering of the stringer plates or by fitting large brackets.

Section 43

SHELL PLATING

Symbols

4301

L = length of ship, in metres (feet),

L_1 = length of ship, in metres (feet), but need not be taken as greater than 215 m (705 ft),

B = moulded breadth, in metres (feet),

D = moulded depth, in metres (feet), to deck at side amidships,

d = moulded draught, in metres (feet),

s = spacing of frames or longitudinals, in mm (in).

Bottom Shell and Keel

4302 The thickness of bottom shell plating amidships is to be that necessary to give the section modulus required by D 4101, but is not to be less than:—

$$t = \frac{s}{3000}\left(L_1 + 75\right)\sqrt{\frac{d}{L_1}}\ \text{mm}$$

$$\left(t = \frac{s}{9{\cdot}84}\left(\frac{L_1 + 246}{1000}\right)\sqrt{\frac{d}{L_1}}\ \text{in}\right)$$

d is not to be taken as less than 0,05L.

The midship thickness is to be maintained from 0,2L aft of amidships to 0,2L forward of amidships and is to be gradually tapered to the end thickness. The midship thickness may be required over an increased extent if shown to be necessary by the bending moment curves.

4303 The width and thickness of the keel over the whole length are not to be less than the values derived from the following formulæ, nor is the thickness to be less than that of the adjacent shell plating.

Width = 70B mm (0·84B in) but need not exceed 1800 mm (71 in).

$$\text{Thickness} = 6 + \frac{L_1}{10}\ \text{mm} \qquad \left(0{\cdot}235 + \frac{12L_1}{10\,000}\ \text{in}\right)$$

Bilge Plating

4304 The thickness of the bilge plating is not to be less than that determined from 4302 using an equivalent spacing s_1:—

$$s_1 = Kl\ \text{mm (in)}$$

where $K = 1{,}06 - 0{,}39\dfrac{l}{R}$, but need not exceed 1,0.

s_1 is to be calculated for each panel of bilge plating (using values of l and R determined as given below) and the greatest value is to be used.

(*a*) Between adjacent longitudinals within the bilge:—

R = r mm (in),

l = distance between adjacent longitudinals, in mm (in).

(*b*) Between lowest side longitudinal and top bilge longitudinal:—

$$R = \frac{r}{1 - \left(\dfrac{b - r}{l}\right)}\ \text{mm (in)},$$

l = distance between lowest side longitudinal and top bilge longitudinal, in mm (in).

(*c*) Between outboard bottom longitudinal and lowest bilge longitudinal:—

$$R = \frac{r}{1 - \left(\dfrac{a - r}{l}\right)}\ \text{mm (in)},$$

l = distance between outboard bottom longitudinal and lowest bilge longitudinal, in mm (in).

In (*a*), (*b*) and (*c*) above

r = radius of bilge, in mm (in),

a = horizontal distance between ship's side and outboard bottom longitudinal, in mm (in),

b = vertical distance between ship's bottom and lowest side longitudinal, in mm (in).

NOTES:—

1 The values of a and b are not to be taken as less than r.

2 l is to be measured in a straight line between the intersections of the longitudinals and the plating.

Side Shell

4305 Within 0,4L amidships the thickness of side shell plating is not to be less than required by the following formulæ:—

(a) with longitudinal framing

$$t = 0{,}0059\, s\sqrt{d}\ \text{mm} \qquad \left(t = \frac{s}{308}\sqrt{d}\ \text{in}\right)$$

or $t = \frac{s}{1000}\left[10{,}6 + \frac{L_1}{30{,}5}\right]$ mm

$$\left(t = \frac{s}{1000}\left[10\cdot 6 + \frac{L_1}{100}\right] \text{in}\right)$$

whichever is the greater.

(b) with transverse framing

$$t = \frac{s + 150}{640}\sqrt{\frac{d\,L}{D}}\ \text{mm} \quad \left(t = \frac{s + 6}{1160}\sqrt{\frac{d\,L}{D}}\ \text{in}\right)$$

In no case is the value of s used in the transverse framing formula to be less than

$559 + 1{,}11L$ mm $\left(22 + \frac{L}{75}\text{ in}\right)$ or 865 mm (34 in)

whichever is the lesser.

The thickness of side shell need not exceed that determined from 4302 using the spacing of side shell frames or longitudinals.

4306 The midship thickness of side shell is to be gradually tapered to the end thickness. (*See* 4308).

4307 Where the shear force has to be investigated (*see* D 4104) the thickness of the side shell plating is to be as required by 4305, or the following, whichever is the greater:—

$$t = \frac{F\left(0{,}16 + 0{,}075\,\frac{A_S}{A_L}\right)}{D\,q}\ \text{mm}$$

$$\left(t = \frac{F\left(0\cdot 16 + 0\cdot 075\,\frac{A_S}{A_L}\right)}{12\,D\,q}\ \text{in}\right)$$

where F = shear force in still water, in tonnes (tons), taking into account, where applicable, local forces at transverse bulkheads,

A_S = area of side shell, in cm² (in²), at the section considered, taken as plating area over a depth equal to D,

A_L = area of longitudinal bulkhead, in cm² (in²), at the section considered, taken as the sum of the plating areas from bottom to deck,

q = shear stress, in kg/mm² (ton/in²), as given in Table D 43.1.

NOTE.—The values of A_S and A_L are to be determined using the original thicknesses of side shell and longitudinal bulkhead.

TABLE D 43.1

STATION	SHEAR STRESS	STATION	SHEAR STRESS
	kg/mm² (ton/in²)		kg/mm² (ton/in²)
AP	8,25 (5·23)	5½	7,65 (4·84)
½	7,81 (4·95)	6	7,21 (4·57)
1	7,37 (4·68)	6½	6,77 (4·29)
1½	6,93 (4·40)	7	6,49 (4·13)
2	6,66 (4·24)	7½	6,49 (4·13)
2½	6,49 (4·13)	8	6,66 (4·24)
3	6,60 (4·18)	8½	7,04 (4·46)
3½	6,82 (4·35)	9	7,54 (4·79)
4	7,26 (4·62)	9½	7,98 (5·06)
4½	7,81 (4·95)	FP	8,25 (5·23)
5	8,25 (5·23)	—	—

End Thickness

4308 The thickness of shell plating for 0,05L at the fore end and 0,1L at the aft end is not to be less than:—

$$\left(6{,}5 + \frac{L}{30}\right)\sqrt{\frac{s}{s_b}}\ \text{mm} \quad \left(\left(0\cdot 255 + \frac{L}{2500}\right)\sqrt{\frac{s}{s_b}}\ \text{in}\right)$$

where s_b = standard frame spacing, in mm (in), as given in D 705 and D 706.

Sheerstrake

4309 The width of sheerstrake from 0,25L aft of amidships to 0,2L forward of amidships is not to be less than 150D mm (0·15D ft) but need not exceed 2135 mm (84 in) and the thickness is not to be less than that of the deck plating or side shell, whichever is the greater.

At ends the thickness of sheerstrake may be the same as the side shell.

4310 The thickness of the sheerstrake is to be increased 20 per cent at the ends of the bridge, but this increase is not required if the bridge does not extend to the ship's side.

If the poop front at side extends within 0,25L from amidships the sheerstrake at the break is to be increased by 20 per cent. No increase is required if the poop front at side is 0,3L from amidships or greater. The increase at intermediate positions is to be obtained by interpolation and is to be applied to the tapered thickness of the sheerstrake.

4311 The upper edge of the sheerstrake is to be dressed smooth and kept free of isolated welded fittings or connections. In ships over 150 m (492 ft) in length scupper openings are not to be cut above the deck within 0,5L amidships or in way of breaks of superstructures.

Where a rounded sheerstrake is adopted, the welding of fairleads or other fittings to this plate is to be reduced to a minimum and details are to be submitted for approval.

Openings in Shell

4312 Sea inlets in pump rooms situated within 0,5L amidships, are, if practicable, to be fitted clear of the bilge radius. All openings are to be arranged so as to minimise discontinuity of transverse frames, longitudinals or bilge keels. Compensation is to be provided for all openings within 0,5L amidships and may be required for openings in the vicinity of the poop front. The compensation should, if possible, take the form of an insert plate rather than a doubler.

If openings are not circular or oval the corners are to be rounded with as large a radius as practicable.

Bilge Keels

4313 Where bilge keels are fitted, it is desirable that they be attached to a continuous flat bar which may be welded to the shell. Scallops are to be arranged in way of welded butts in the flat bar. Alternative arrangements, or arrangements omitting the flat bar, will be specially considered.

Bilge keels are to be gradually tapered at their ends and are not to finish on an unstiffened panel.

Section 44

BOTTOM, SIDE AND DECK LONGITUDINALS

Symbols

4401

L_1 = length of ship, in metres (feet), but need not be taken as greater than 215 m (705 ft),

D = moulded depth, in metres (feet),

D_1 = moulded depth, in metres (feet), but not to be taken as greater than 20 m (65·6 ft),

S = span, in metres (feet), measured between transverses or from transverse to "span point" (minimum value 2,5 m (8·2 ft)),

s = spacing of longitudinals, in mm (in),

h = distance of longitudinal below deck at side, in metres (feet).

Scantlings

4402 The scantlings of longitudinals within the range of cargo tanks are not to be less than required by the following formulæ:—

Bottom longitudinals $$\frac{I}{y} = \frac{s\,S^2\,D}{74}\ \text{cm}^3$$

$$\left(\frac{I}{y} = \frac{s\,S^2\,D}{1680}\ \text{in}^3\right)$$

Deck longitudinals $$\frac{I}{y} = \frac{s\,S^2}{100}\left\{1{,}85 + \left(\frac{L_1}{109{,}7}\right)^3\right\}\ \text{cm}^3$$

$$\left(\frac{I}{y} = \frac{s\,S^2}{1200}\left\{3{\cdot}2 + \left(\frac{L_1}{300}\right)^3\right\}\ \text{in}^3\right)$$

Side longitudinals $$\frac{I}{y} = \frac{s\,S^2}{118}\left(h + \frac{D_1}{6}\right)\ \text{cm}^3$$

$$\left(\frac{I}{y} = \frac{s\,S^2}{2680}\left(h + \frac{D_1}{6}\right)\text{in}^3\right)$$

The section modulus given by these formulæ is that of the longitudinal and associated plating. (*See* D 5302.)

The scantlings derived from the above, using the midship thickness of plating, are to extend throughout the cargo tanks.

4403 The scantlings of bilge longitudinals are to be graduated between those required for the bottom and lowest side longitudinals.

4404 Where flat bars are used for longitudinals and these are continuous at bulkheads, the thickness is not to be less than one-eighteenth of the depth; otherwise, the thickness should not be less than one-fifteenth of the depth.

Where built sections are used the breadth of face bar is not to be less than given below:

(a) For longitudinals within 0,15D of base line and deck line

—symmetrical face bars

$$b_F = k_1\,S\ \text{mm}$$

$$(b_F = {\cdot}012\ k_1\,S\ \text{in}).$$

—assymmetrical face bars

$$b_F = k_1 k_3\ S\ \text{mm}$$

$$(b_F = {\cdot}012\ k_1 k_3\ S\ \text{in}).$$

The ratio of web depth to web thickness is not to exceed 55 : 1, i.e. $\frac{t_W}{d}$ is not to be less than 0,0182 (*see also* D 5309).

(b) For longitudinals within 0,35D of mid depth

—symmetrical face bars

$$b_F = k_2\,S\ \text{mm}$$

$$(b_F = {\cdot}012\ k_2\,S\ \text{in}).$$

—assymmetrical face bars

$$b_F = k_2 k_3\ S\ \text{mm}$$

$$(b_F = {\cdot}012\ k_2 k_3\ S\ \text{in}).$$

The ratio of web depth to web thickness is not to exceed 60 : 1, i.e. $\frac{t_W}{d}$ is not to be less than 0,0167 (*see also* D 5309).

where b_F = minimum breadth of face bar, in mm (in),

k_1, k_2 and k_3 are determined from Figs. D 44.1, D 44.2 and D 44.3,

A_W = sectional area of web of longitudinal, in cm^2 (in^2),

A_F = sectional area of face bar, in cm^2 (in^2),

t_W = thickness of web, in mm (in),

d = depth of web, in mm (in),

S = span of longitudinal, in metres (feet), but not to be taken less than 2,44 m (8 ft).

Note:—Figs. D 44.1, D 44.2 and D 44.3 represent the following formulæ:—

$$k_1 = 25\sqrt{1 + \frac{A_W}{2\,A_F}\left[1 - \left(\frac{20\,t_W}{d}\right)^2\right]}$$

$$k_2 = 20\sqrt{1 + \frac{A_W}{1{,}66\,A_F}\left[1 - \left(\frac{25\,t_W}{d}\right)^2\right]}$$

$$k_3 = \frac{1}{\sqrt{1 + 0{,}35\sqrt{\frac{A_W}{A_F}}}}$$

Higher Tensile Steel

4405 For additional requirements when higher tensile steel is used, *see* D 6704.

Connections

4406 End connections of longitudinals to bulkheads are to provide adequate fixity and, so far as practicable, direct continuity of longitudinal strength.

4407 Where the length exceeds 215 m (705 ft) it is desirable that the bottom and deck longitudinals be continuous through the transverse bulkheads but alternative arrangements will be specially considered.

4408 Longitudinals are to be connected to the transverses as required by Table D 57.6. In ships above 200 m (656 ft) all longitudinals (including those on longitudinal bulkheads) are to have the web attached to the transverses. In ships between 155 and 200 m (508 and 656 ft), similar arrangements are to be made except that side longitudinals and longitudinal bulkhead horizontal stiffeners need not have the webs attached unless they are within 3 m (9·84 ft) of the bottom or deck.

Section 45

TRANSVERSE SIDE FRAMING

Symbols

4501

D = moulded depth, in metres (feet), to deck at side amidships,

S = span, in metres (feet), measured between stringers or from stringer to "span point",

s = frame spacing, in mm (in),

h = head, in metres (feet), from mid-point of span to deck at side measured at mid-length of tank.

Scantlings

4502 Where, in tankers not exceeding 200 m (656 ft) in length, transverse side framing is adopted in the cargo tanks, the section modulus of side frames is not to be less than:—

$$\frac{I}{y} = \frac{s\,h\,S^2}{97{,}5}\ \text{cm}^3 \qquad \left(\frac{I}{y} = \frac{s\,h\,S^2}{2220}\ \text{in}^3\right)$$

where side transverses are fitted,

$$\text{or} \quad \frac{I}{y} = \frac{s\,h\,S^2}{83{,}3}\ \text{cm}^3 \qquad \left(\frac{I}{y} = \frac{s\,h\,S^2}{1890}\ \text{in}^3\right)$$

where side transverses are not fitted.

The size of the frame is to be governed by the maximum modulus derived from the above formula and is to be maintained for the full depth of the ship. The modulus given is that of the frame and associated side shell plating. (*See* D 5302.)

Side Stringers

4503 Where the depth D does not exceed 7,5 m (25 ft), one side stringer is to be fitted. Where D exceeds 7,5 m (25 ft) but does not exceed 11 m (36 ft), 2 stringers are required and over 11 m (36 ft) depth, 3 stringers. For scantlings of stringers, *see* D 4703.

Side Transverses

4504 Where the depth D exceeds 11 m (36 ft), or the distance between transverse bulkheads (whether oiltight or non-oiltight) exceeds 15 m (49 ft), side transverses are to be fitted in line with the bottom transverses. The scantlings of the side transverses are to be determined in accordance with D 4607.

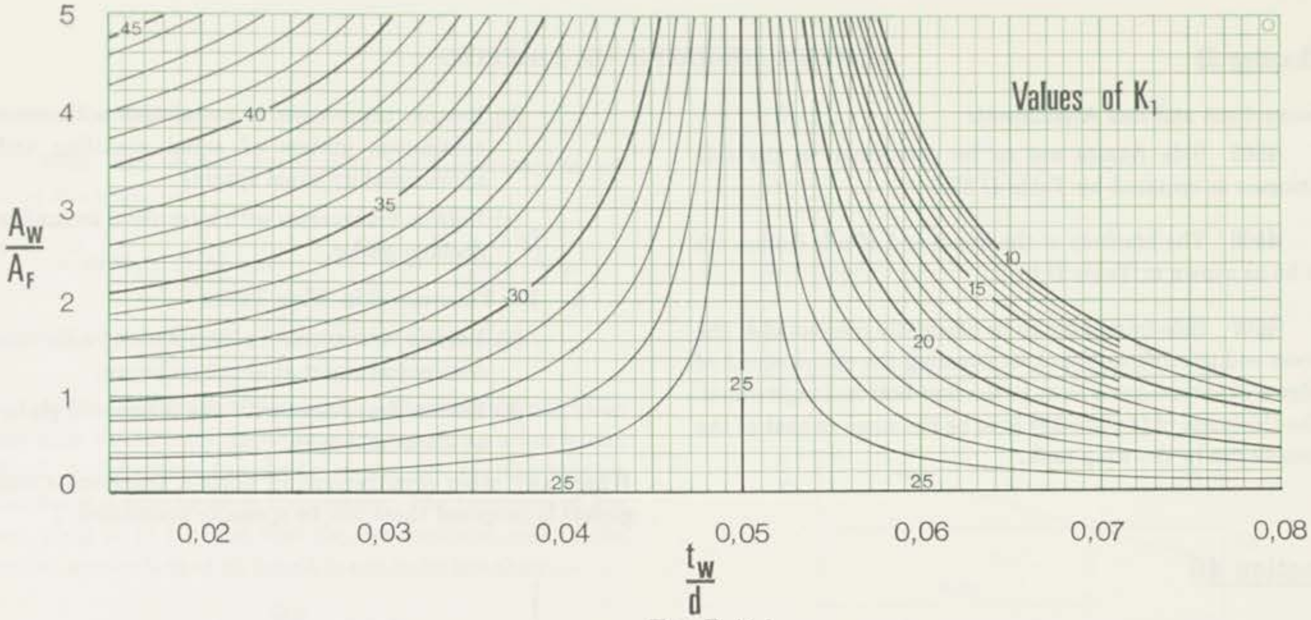


FIG. D 44.1

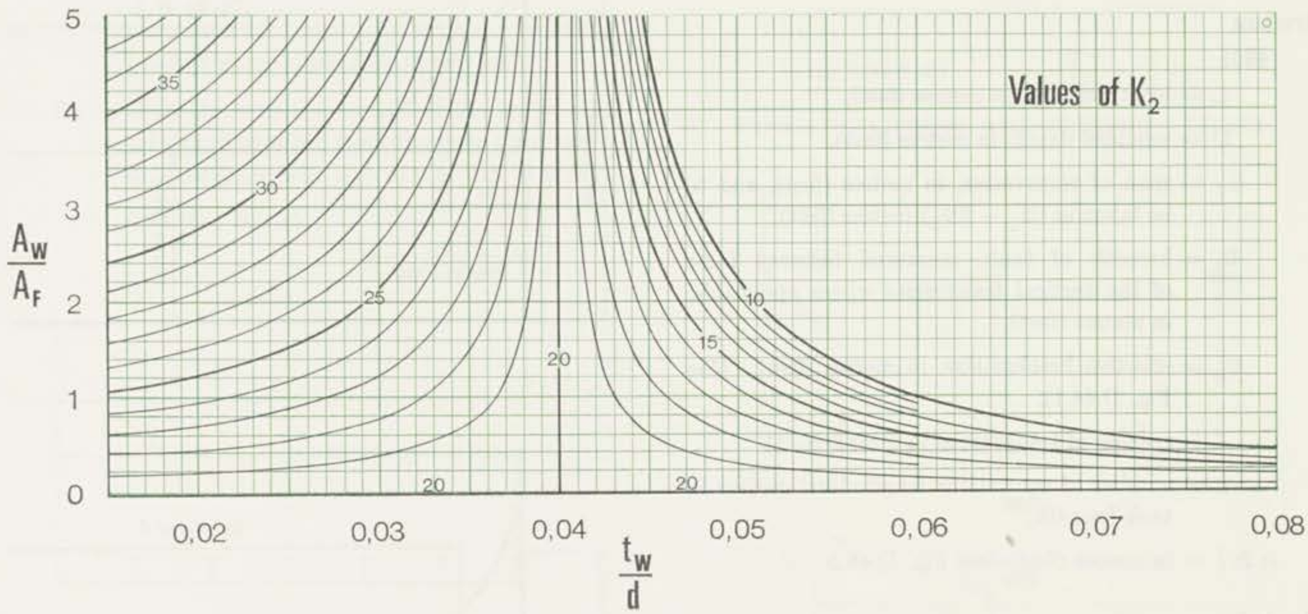


FIG. D 44.2

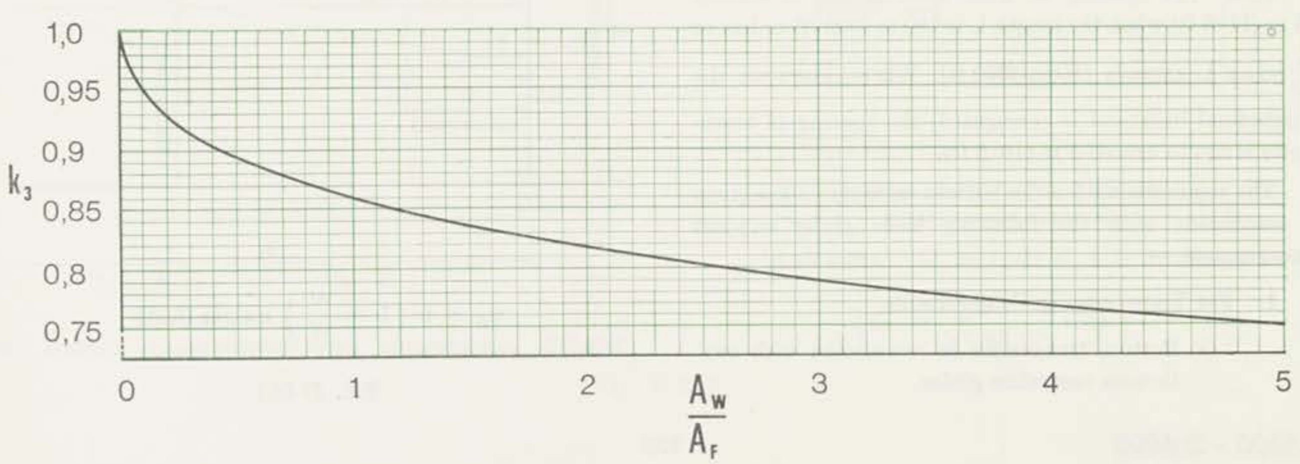


FIG. D 44.3

Connections and End Attachments

4505 Side frames are to be connected to the side stringers as required by Table D 57.6.

4506 The brackets at the upper end of side frames are to be as shown in Table D 57.5.

4507 Side frames are to be efficiently connected at the lower end to stiffened brackets covering the entire round of bilge and extending at least to the first bottom longitudinal. The thickness of the bracket is to be the same as that of the transverses in the wing tank.

Section 46

BOTTOM, SIDE AND DECK TRANSVERSES

Symbols

4601

L = length of ship, in metres (feet),

D = moulded depth, in metres (feet),

S_T = span of transverses, in metres (feet), and to be taken as $(b_t - 2b_e)$ metres (feet),

b_t = breadth of tank, measured between faces of the vertical transverses where applicable, in metres (feet),

b_e = effective bracket size, in metres (feet). (*See* Fig. D 46.1),

s = spacing of transverses, in metres (feet),

n = number of continuous longitudinal girders in tank breadth,

h & l = in metres (feet)—*see* Fig. D 46.3.

General

4602 The spacing of transverses is not to exceed 3,6 m (11·8 ft) when the length L is 180 m (590 ft) or less or $\frac{L}{50}$ when L exceeds 180 m (590 ft). Where, however, the longitudinal bulkhead is corrugated, the spacing of transverses is not to exceed 5 m (16·5 ft).

The requirements for the bottom transverses are given in association with the following basic girder support arrangements:—

1. For Transverses in Centre Tanks

   (a) Bottom transverses in association with continuous centreline girder.

   (b) Bottom transverses in association with three continuous girders of equal scantling and approximately equal spacing.

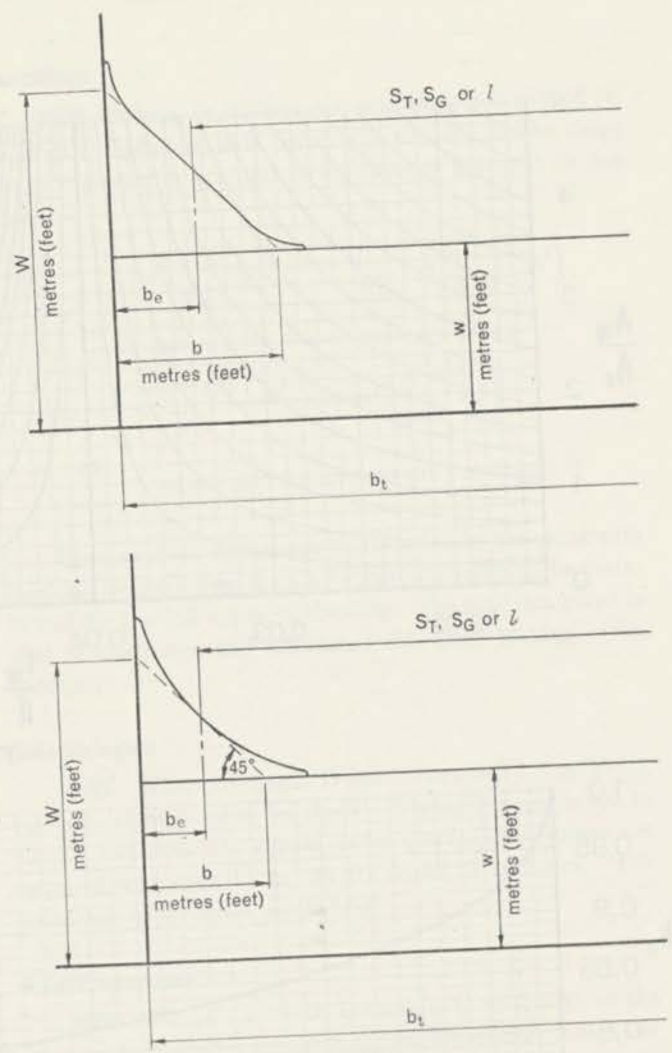
   (c) Bottom transverses with intercostal centreline docking girder.

2. For Transverses in Wing Tanks

   (a) Bottom transverse in association with one continuous girder at about mid-span.

   (b) Bottom transverse with one intercostal girder at about mid-span.

Where any other arrangement of bottom transverses and girders is proposed these will be specially considered.



$$b_e = b\left(1 - \frac{w}{W}\right) \text{ metres (feet)}$$

Fig. D 46.1

Bottom Transverses

4603 The section modulus of the transverses is not to be less than:—

$$\frac{I}{y} = 62\ K_1\ s\ D\ S_T^2\ \text{cm}^3 \qquad \left(\frac{I}{y} = \frac{K_1\ s\ D\ S_T^2}{30 \cdot 63}\ \text{in}^3\right)$$

where K_1 is a coefficient obtained from Table D 46.1.

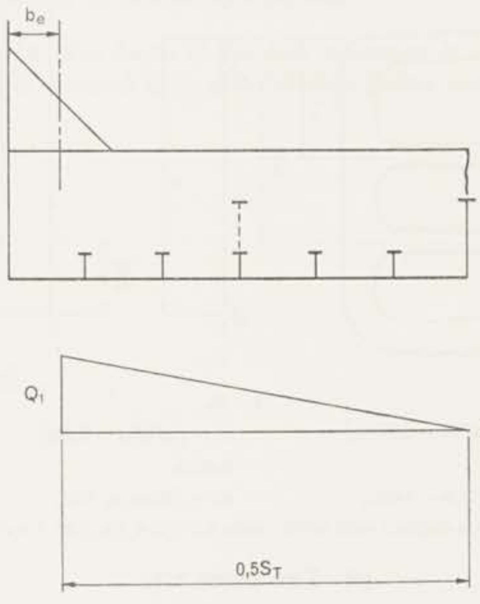
4604 The depth of the bottom transverse is not to be less than either one fifth of its span, between girders where fitted, or 2,5 times the depth of the slot for the bottom longitudinal whichever is the greater. The thickness of the web plate is to be such that the net sectional area of the web at any section of its length is not to be less than:—

$$A = \frac{Qx}{F}\ \text{cm}^2\ (\text{in}^2)$$

where A = net sectional area of the web, including bracket where applicable, in cm^2 (in^2),

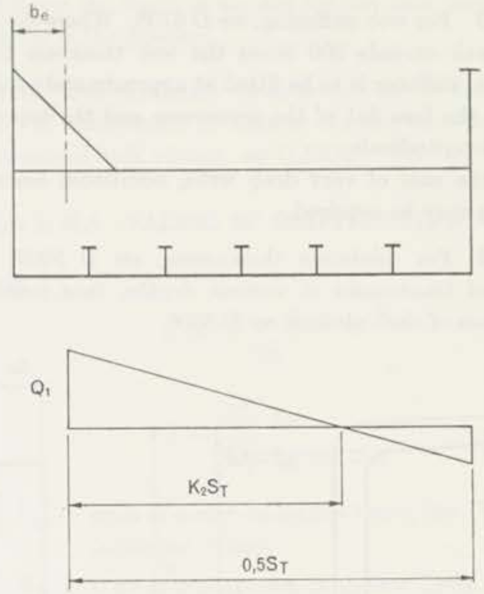
Qx = shear force at the actual section under consideration obtained from diagrams constructed in accordance with a, b or c of Fig. D 46.2,

F = 0,85 (5·4 British).



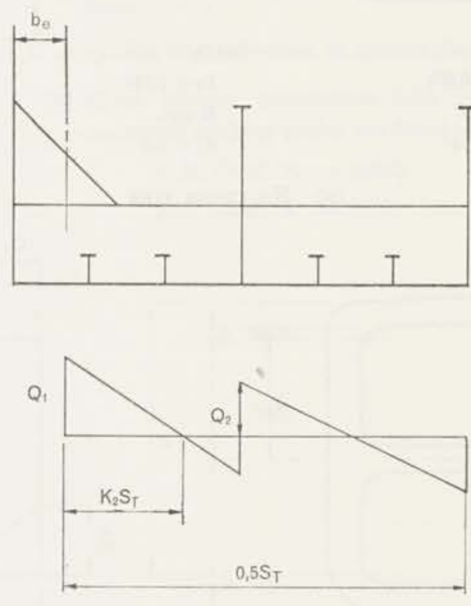
$K_2 = 0{,}5$ $\qquad Q_2 = 0$

(*a*) Bottom transverses with intercostal girders



K_2 see Table D 46.1 $\qquad Q_2 = \left[\frac{1}{2K_2} - 1\right] Q_1$

(*b*) Bottom transverses with continuous girder



K_2 see Table D 46.1 $\qquad Q_2 = 0{,}5Q_1$

(*c*) Bottom transverse with three continuous girders

In all cases $\quad Q_1 = 1{,}025\ K_2\ s\ D\ S_T$ tonnes

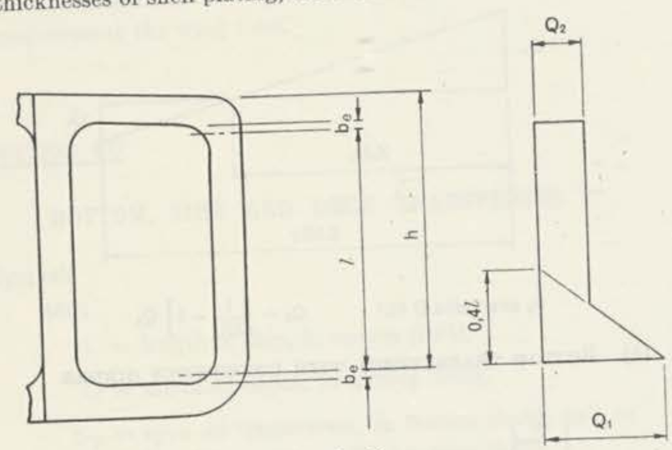
$$\left(Q_1 = \frac{K_2\ s\ D\ S_T}{35}\ \text{tons}\right)$$

Fig. D 46.2

4605 For web stiffening, *see* D 5708. Where the depth of the web exceeds 200 times the web thickness then a horizontal stiffener is to be fitted at approximately midway between the face flat of the transverse and the top of the bottom longitudinals.

In the case of very deep webs, additional horizontal stiffening may be required.

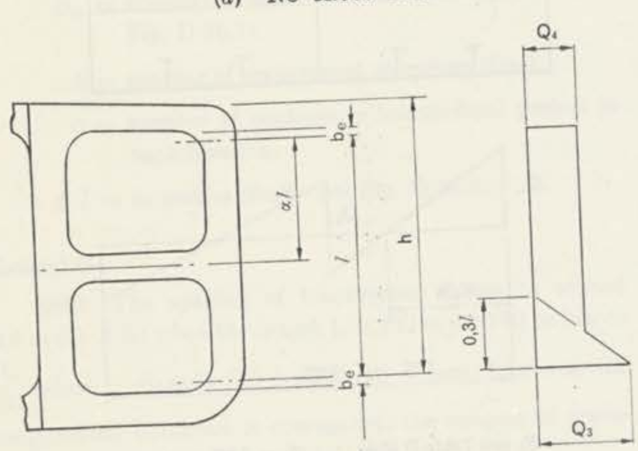
4606 For minimum thicknesses, *see* D 5309. For moduli of transverses of various depths, face areas and thicknesses of shell plating, *see* D 5306.



For Q_1
$K_2 = 0{,}359$
British
$K_2 = 10$

For Q_2
$K_2 = 0{,}154$
British
$K_2 = 4{\cdot}3$

(*a*) No cross ties



For Q_3
$K_2 = [0{,}455 - 0{,}316\alpha]$
British
$K_2 = [12{\cdot}7 - 8{\cdot}8\alpha]$

For Q_4
$K_2 = 0{,}103$
British
$K_2 = 2{\cdot}86$

Shear force diagram valid within limits $0{,}5 \leqslant \alpha \leqslant 0{,}7$

(*b*) One cross tie

Side Transverses

4607 The section modulus of the transverse is not to be less than:—

$$\frac{I}{y} = K_1 \, s \, h \, l^2 \text{ cm}^3 \qquad \left(\frac{I}{y} = \frac{K_1 \, s \, h \, l^2}{10\,000} \text{ in}^3\right)$$

where $K_1 = 3{,}72$ (19·6 British) where no cross-tie fitted,
2,16 (11·4 British) where one cross-tie fitted,
1,88 (9·9 British) where two or more cross-ties fitted.

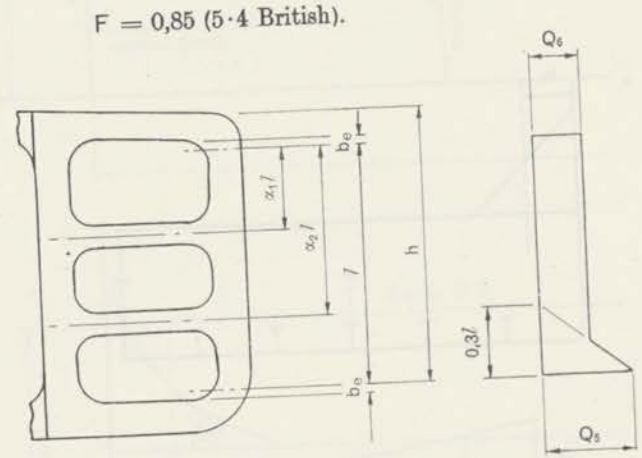
4608 The depth of the side transverse web is not to be less than 2,5 times the depth of the slot for the adjacent side longitudinals and the thickness of the web is to be such that the net sectional area of the web at any section is not to be less than:—

$$A = \frac{Qx}{F} \text{ cm}^2 \text{ (in}^2\text{)}$$

where A = net sectional area of the web, including bracket where applicable, in cm² (in²),

Qx = shear force at the actual section under consideration obtained from diagrams constructed in accordance with a, b or c of Fig. D 46.3,

$F = 0{,}85$ (5·4 British).



For Q_5
$K_2 = [0{,}441 - 0{,}267\alpha_2]$
British
$K_2 = [12{\cdot}3 - 7{\cdot}44\alpha_2]$

For Q_6
$K_2 = [0{,}498\alpha_2 - 0{,}249]$
British
$K_2 = [13{\cdot}9\alpha_2 - 6{\cdot}95]$

Shear force diagram valid within limits $0{,}4 \leqslant \alpha_1 \leqslant 0{,}5$; $0{,}65 \leqslant \alpha_2 \leqslant 0{,}8$

(*c*) Two cross ties

In all cases $Q = K_2 \, h \, s \, l$ tonnes

$$\left(Q = \frac{K_2 \, h \, s \, l}{1000} \text{ tons}\right)$$

Fig. D 46.3

4609 For web stiffening, *see* D 5708. Where the depth of the web exceeds 100 times the web thickness then a vertical stiffener is to be fitted at approximately mid-depth.

4610 If side transverses are tapered, the increase in depth at the bottom, and decrease at the top, is not to exceed 10 per cent of the mean depth.

4611 For minimum thicknesses, *see* D 5309. For moduli of transverses of various depths, face areas and thicknesses of shell plating, *see* D 5306.

Deck Transverses

4612 The section modulus of the transverses is not to be less than:—

$$\frac{I}{y} = 53{,}75\,(0{,}0269\,s\,L + 0{,}8)\,(S_1 + 1{,}83)\ \text{cm}^3$$

$$\left(\frac{I}{y} = (0{\cdot}0025\,s\,L + 0{\cdot}8)\,(S_1 + 6)\ \text{in}^3\right)$$

$$S_1 = \frac{S_T}{(n+1)}\ \text{metres (feet)}$$

but not less than $\frac{b_t}{6}$.

4613 If intercostal side girders are fitted, and their scantlings are in accordance with D 4811, the modulus of the deck transverses derived in accordance with the above formula may be reduced by 5 per cent.

4614 The depth of the deck transverse is not to be less than one sixth of its span, between girders where fitted, or 2,5 times the depth of the slot for the deck longitudinal, whichever is the greater.

4615 For minimum thicknesses, *see* D 5309. For moduli of transverses of various depths, face areas and thicknesses of deck plating, *see* D 5306.

TABLE D 46.1—VALUES OF COEFFICIENTS K_1 AND K_2

General

$$\alpha = \frac{l_T - S_G}{2s}$$

$$\beta = \frac{S_G^3}{S_T^3}\,\frac{I_T}{I_G}$$

where S_G = span of girder, in metres (feet), (*see* D 4803 for minimum value),

S_T = span of transverses, in metres (feet),

I_G = inertia of girder, in cm^4 (in^4),

I_T = inertia of transverses, in cm^4 (in^4),

l_T = distance between support bulkheads, in metres (feet),

s = spacing of transverses, in metres (feet).

(a) where bottom transverses with intercostal centreline docking girder are fitted:—

B.M. Coeff. $K_1 = 0{,}083$

S.F. Coeff. $K_2 = 0{,}50$

TABLE D 46.1

(b) 1 GIRDER 2 TRANSVERSES

GIRDER

β	B.M. COEFF. K_1						S.F. COEFF. K_2					
	α						α					
	0,0	0,2	0,4	0,6	0,8	1,0	0,0	0,2	0,4	0,6	0,8	1,0
0,02	0,210	0,210	0,195	0,175	0,125	0,0	1,000	1,000	1,000	1,000	1,000	1,000
0,04	0,210	0,210	0,195	0,175	0,125	0,0	0,960	0,960	0,980	1,000	1,000	1,000
0,06	0,210	0,210	0,195	0,170	0,125	0,0	0,940	0,940	0,960	0,980	1,000	1,000
0,08	0,205	0,205	0,190	0,167	0,125	0,0	0,920	0,920	0,940	0,970	1,000	1,000
0,10	0,200	0,200	0,185	0,165	0,125	0,0	0,900	0,900	0,920	0,960	0,990	1,000
0,20	0,180	0,180	0,170	0,150	0,120	0,0	0,800	0,820	0,860	0,920	0,980	1,000
0,40	0,150	0,150	0,150	0,135	0,115	0,0	0,670	0,730	0,760	0,840	0,950	1,000
0,60	0,130	0,130	0,135	0,125	0,110	0,0	0,580	0,630	0,690	0,790	0,910	1,000
0,80	0,120	0,120	0,120	0,120	0,105	0,0	0,520	0,540	0,630	0,730	0,880	1,000
1,00	0,100	0,100	0,115	0,115	0,100	0,0	0,460	0,500	0,580	0,680	0,850	1,000

TRANSVERSES

β	B.M. COEFF. K_1						S.F. COEFF. K_2					
	α						α					
	0,0	0,2	0,4	0,6	0,8	1,0	0,0	0,2	0,4	0,6	0,8	1,0
0,02	0,022	0,022	0,022	0,022	0,021	0,020	0,255	0,255	0,255	0,255	0,250	0,250
0,04	0,023	0,023	0,023	0,022	0,021	0,020	0,263	0,263	0,257	0,255	0,250	0,250
0,06	0,025	0,025	0,023	0,022	0,021	0,020	0,265	0,265	0,263	0,260	0,250	0,250
0,08	0,026	0,026	0,024	0,023	0,021	0,020	0,270	0,270	0,267	0,260	0,253	0,250
0,10	0,027	0,027	0,025	0,023	0,022	0,020	0,275	0,275	0,270	0,263	0,255	0,250
0,20	0,033	0,033	0,029	0,026	0,023	0,020	0,300	0,300	0,285	0,272	0,257	0,250
0,40	0,041	0,041	0,036	0,032	0,025	0,020	0,330	0,330	0,307	0,287	0,265	0,250
0,60	0,047	0,047	0,041	0,036	0,026	0,020	0,355	0,355	0,325	0,302	0,273	0,250
0,80	0,051	0,051	0,045	0,038	0,028	0,020	0,370	0,370	0,342	0,315	0,278	0,250
1,00	0,054	0,054	0,048	0,041	0,030	0,020	0,385	0,385	0,355	0,327	0,285	0,250

TABLE D 46.1—*continued*

(b) 1 GIRDER 3 TRANSVERSES

GIRDER												
β	B.M. COEFF. K_1						S.F. COEFF. K_2					
	α						α					
	0,0	0,2	0,4	0,6	0,8	1,0	0,0	0,2	0,4	0,6	0,8	1,0
0,02	0,290	0,290	0,290	0,270	0,200	0,120	1,400	1,400	1,500	1,500	1,500	1,500
0,04	0,290	0,290	0,290	0,270	0,200	0,120	1,400	1,400	1,500	1,500	1,500	1,500
0,06	0,290	0,290	0,290	0,260	0,200	0,120	1,380	1,400	1,500	1,500	1,500	1,500
0,08	0,280	0,280	0,280	0,250	0,195	0,115	1,340	1,370	1,470	1,470	1,480	1,500
0,10	0,275	0,275	0,275	0,240	0,190	0,115	1,320	1,340	1,420	1,440	1,460	1,480
0,20	0,245	0,245	0,245	0,220	0,175	0,105	1,180	1,210	1,280	1,330	1,380	1,450
0,40	0,200	0,200	0,200	0,185	0,160	0,090	0,970	1,030	1,080	1,200	1,280	1,420
0,60	0,170	0,170	0,170	0,170	0,145	0,080	0,840	0,900	0,960	1,110	1,210	1,380
0,80	0,150	0,150	0,150	0,150	0,135	0,075	0,740	0,800	0,870	1,040	1,150	1,330
1,00	0,135	0,135	0,135	0,135	0,125	0,070	0,680	0,740	0,810	0,960	1,100	1,300

TRANSVERSES												
β	B.M. COEFF. K_1						S.F. COEFF. K_2					
	α						α					
	0,0	0,2	0,4	0,6	0,8	1,0	0,0	0,2	0,4	0,6	0,8	1,0
0,02	0,025	0,025	0,024	0,023	0,022	0,022	0,258	0,258	0,257	0,252	0,252	0,252
0,04	0,026	0,026	0,025	0,024	0,023	0,023	0,267	0,267	0,267	0,262	0,262	0,260
0,06	0,028	0,028	0,026	0,026	0,025	0,024	0,275	0,275	0,275	0,270	0,270	0,265
0,08	0,030	0,030	0,028	0,028	0,026	0,026	0,285	0,285	0,280	0,272	0,272	0,272
0,10	0,032	0,032	0,029	0,029	0,028	0,027	0,292	0,292	0,287	0,277	0,275	0,275
0,20	0,040	0,040	0,037	0,035	0,033	0,032	0,325	0,325	0,315	0,310	0,300	0,282
0,40	0,052	0,052	0,049	0,046	0,041	0,039	0,372	0,372	0,360	0,345	0,332	0,320
0,60	0,059	0,059	0,057	0,054	0,048	0,045	0,405	0,405	0,392	0,375	0,357	0,342
0,80	0,065	0,065	0,063	0,059	0,053	0,049	0,425	0,425	0,415	0,390	0,377	0,360
1,00	0,069	0,069	0,066	0,063	0,056	0,052	0,440	0,440	0,432	0,415	0,395	0,375

TABLE D 46.1—*continued*

(b) 1 GIRDER 4 TRANSVERSES

GIRDER												
β	B.M. COEFF. K_1						S.F. COEFF. K_2					
	α						α					
	0,0	0,2	0,4	0,6	0,8	1,0	0,0	0,2	0,4	0,6	0,8	1,0
0,02	0,370	0,350	0,330	0,315	0,275	0,215	1,890	1,890	1,920	1,940	1,960	1,990
0,04	0,370	0,350	0,330	0,315	0,275	0,215	1,870	1,870	1,900	1,930	1,940	1,960
0,06	0,360	0,350	0,330	0,310	0,270	0,205	1,820	1,820	1,870	1,890	1,920	1,940
0,08	0,350	0,340	0,320	0,300	0,260	0,200	1,760	1,800	1,820	1,840	1,880	1,920
0,10	0,340	0,330	0,315	0,290	0,255	0,195	1,700	1,750	1,790	1,830	1,860	1,900
0,20	0,300	0,300	0,275	0,260	0,230	0,180	1,500	1,580	1,630	1,700	1,780	1,820
0,40	0,240	0,240	0,230	0,220	0,200	0,155	1,240	1,300	1,400	1,540	1,620	1,700
0,60	0,200	0,200	0,200	0,200	0,175	0,135	1,060	1,120	1,250	1,400	1,500	1,600
0,80	0,175	0,175	0,175	0,175	0,165	0,120	0,940	1,000	1,150	1,270	1,420	1,520
1,00	0,150	0,150	0,150	0,150	0,150	0,105	0,850	0,920	1,050	1,200	1,340	1,460

TRANSVERSES												
β	B.M. COEFF. K_1						S.F. COEFF. K_2					
	α						α					
	0,0	0,2	0,4	0,6	0,8	1,0	0,0	0,2	0,4	0,6	0,8	1,0
0,02	0,025	0,025	0,024	0,024	0,023	0,023	0,255	0,255	0,255	0,255	0,253	0,250
0,04	0,027	0,026	0,026	0,025	0,025	0,024	0,272	0,270	0,268	0,266	0,260	0,255
0,06	0,029	0,029	0,028	0,027	0,026	0,025	0,282	0,280	0,275	0,272	0,270	0,263
0,08	0,031	0,031	0,030	0,028	0,028	0,027	0,292	0,287	0,285	0,280	0,275	0,270
0,10	0,033	0,033	0,032	0,030	0,029	0,028	0,300	0,295	0,290	0,285	0,280	0,275
0,20	0,042	0,041	0,039	0,037	0,035	0,033	0,335	0,325	0,320	0,313	0,307	0,300
0,40	0,053	0,051	0,050	0,047	0,044	0,041	0,380	0,372	0,362	0,352	0,342	0,330
0,60	0,061	0,059	0,057	0,054	0,050	0,047	0,412	0,405	0,387	0,376	0,365	0,355
0.80	0,066	0,065	0,062	0,058	0,054	0,051	0,435	0,425	0,412	0,400	0,382	0,370
1,00	0,070	0,068	0,065	0,062	0,058	0,055	0,450	0,437	0,427	0,412	0,395	0,385

TABLE D 46.1—*continued*

(b) 1 GIRDER 5 TRANSVERSES

GIRDER												
β	B.M. COEFF. K_1						S.F. COEFF. K_2					
	α						α					
	0,0	0,2	0,4	0,6	0,8	1,0	0,0	0,2	0,4	0,6	0,8	1,0
0,02	0,455	0,440	0,410	0,380	0,345	0,300	2,330	2,350	2,370	2,400	2,420	2,450
0,04	0,445	0,430	0,410	0,380	0,345	0,300	2,310	2,340	2,360	2,380	2,410	2,440
0,06	0,430	0,415	0,395	0,370	0,340	0,295	2,250	2,290	2,300	2,340	2,380	2,400
0,08	0,415	0,400	0,385	0,365	0,330	0,290	2,180	2,230	2,280	2,290	2,340	2,360
0,10	0,400	0,390	0,375	0,355	0,320	0,280	2,110	2,170	2,200	2,240	2,300	2,320
0,20	0,345	0,340	0,330	0,315	0,285	0,250	1,840	1,920	2,000	2,040	2,130	2,180
0,40	0,270	0,265	0,265	0,265	0,235	0,200	1,500	1,600	1,700	1,790	1,900	1,970
0,60	0,220	0,220	0,220	0,220	0,200	0,165	1,280	1,380	1,500	1,610	1,650	1,840
0,80	0,185	0,185	0,185	0,185	0,175	0,140	1,140	1,230	1,370	1,500	1,620	1,740
1,00	0,165	0,165	0,165	0,165	0,160	0,125	1,040	1,140	1,280	1,420	1,540	1,650

TRANSVERSES												
β	B.M. COEFF. K_1						S.F. COEFF. K_2					
	α						α					
	0,0	0,2	0,4	0,6	0,8	1,0	0,0	0,2	0,4	0,6	0,8	1,0
0,02	0,025	0,025	0,025	0,024	0,024	0,023	0,265	0,265	0,263	0,260	0,257	0,255
0,04	0,028	0,028	0,028	0,027	0,026	0,025	0,280	0,280	0,275	0,270	0,267	0,265
0,06	0,031	0,031	0,030	0,029	0,028	0,027	0,290	0,287	0,284	0,280	0,277	0,275
0,08	0,034	0,034	0,033	0,032	0,031	0,030	0,303	0,300	0,295	0,290	0,287	0,283
0,10	0,037	0,036	0,036	0,034	0,033	0,032	0,312	0,309	0,305	0,300	0,297	0,292
0,20	0,046	0,046	0,045	0,043	0,043	0,041	0,352	0,349	0,343	0,337	0,330	0,325
0,40	0,060	0,058	0,057	0,055	0,054	0,053	0,405	0,402	0,393	0,383	0,378	0,375
0,60	0,068	0,067	0,065	0,064	0,063	0,061	0,435	0,432	0,426	0,417	0,412	0,407
0,80	0,073	0,072	0,071	0,069	0,068	0,067	0,455	0,452	0,446	0,440	0,436	0,432
1,00	0,077	0,076	0,074	0,073	0,071	0,070	0,470	0,467	0,461	0,455	0,450	0,445

TABLE D 46.1—*continued*

(c) 3 GIRDERS 2 TRANSVERSES

GIRDERS												
β	B.M. COEFF. K_1						S.F. COEFF. K_2					
	α						α					
	0,0	0,2	0,4	0,6	0,8	1,0	0,0	0,2	0,4	0,6	0,8	1,0
0,02	0,240	0,230	0,220	0,195	0,135	0,0	1,000	1,000	1,000	1,000	1,000	1,000
0,04	0,240	0,230	0,220	0,195	0,135	0,0	1,000	1,000	1,000	1,000	1,000	1,000
0,06	0,240	0,230	0,220	0,195	0,135	0,0	1,000	1,000	1,000	1,000	1,000	1,000
0,08	0,240	0,230	0,220	0,195	0,135	0,0	1,000	1,000	1,000	1,000	1,000	1,000
0,10	0,240	0,230	0,220	0,195	0,135	0,0	1,000	1,000	1,000	1,000	1,000	1,000
0,20	0,235	0,227	0,219	0,195	0,135	0,0	1,000	1,000	1,000	1,000	1,000	1,000
0,40	0,215	0,215	0,200	0,189	0,135	0,0	0,960	0,980	1,000	1,000	1,000	1,000
0,60	0,195	0,195	0,195	0,180	0,135	0,0	0,870	0,900	0,950	1,000	1,000	1,000
0,80	0,175	0,175	0,175	0,170	0,135	0,0	0,790	0,840	0,890	1,000	1,000	1,000
1,00	0,165	0,165	0,165	0,160	0,125	0,0	0,720	0,770	0,840	0,960	1,000	1,000

TRANSVERSES												
β	B.M. COEFF. K_1						S.F. COEFF. K_2					
	α						α					
	0,0	0,2	0,4	0,6	0,8	1,0	0,0	0,2	0,4	0,6	0,8	1,0
0,02	0,007	0,006	0,006	0,005	0,005	0,005	0,147	0,145	0,140	0,137	0,137	0,125
0,04	0,009	0,007	0,007	0,006	0,005	0,005	0,147	0,145	0,140	0,137	0,137	0,125
0,06	0,010	0,008	0,008	0,007	0,006	0,005	0,155	0,152	0,142	0,137	0,137	0,125
0,08	0,011	0,009	0,009	0,008	0,007	0,005	0,163	0,157	0,150	0,140	0,137	0,125
0,10	0,013	0,011	0,011	0,009	0,007	0,005	0,167	0,165	0,155	0,145	0,137	0,125
0,20	0,018	0,015	0,015	0,012	0,008	0,005	0,195	0,186	0,180	0,162	0,144	0,125
0,40	0,026	0,023	0,021	0,017	0,010	0,005	0,235	0,220	0,210	0,185	0,152	0,125
0,60	0,032	0,029	0,025	0,020	0,011	0,005	0,262	0,247	0,232	0,202	0,160	0,125
0,80	0,037	0,033	0,029	0,022	0,013	0,005	0,285	0,270	0,250	0,217	0,165	0,125
1,00	0,041	0,038	0,033	0,025	0,014	0,005	0,302	0,287	0,267	0,230	0,170	0,125

TABLE D 46.1—*continued*

(c) 3 GIRDERS 3 TRANSVERSES

GIRDERS												
	B.M. COEFF. K_1						S.F. COEFF. K_2					
β	α						α					
	0,0	0,2	0,4	0,6	0,8	1,0	0,0	0,2	0,4	0,6	0,8	1,0
0,02	0,335	0,325	0,300	0,265	0,210	0,140	1,620	1,620	1,620	1,620	1,620	1,620
0,04	0,335	0,325	0,300	0,265	0,210	0,140	1,620	1,620	1,620	1,620	1,620	1,620
0,06	0,335	0,325	0,300	0,265	0,210	0,140	1,620	1,620	1,620	1,620	1,620	1,620
0,08	0,335	0,325	0,300	0,265	0,210	0,140	1,620	1,620	1,620	1,620	1,620	1,620
0,10	0,335	0,325	0,300	0,265	0,210	0,140	1,620	1,620	1,620	1,620	1,620	1,620
0,20	0,325	0,310	0,290	0,260	0,210	0,140	1,540	1,620	1,620	1,620	1,620	1,620
0,40	0,285	0,275	0,265	0,240	0,200	0,125	1,370	1,420	1,460	1,500	1,500	1,500
0,60	0,255	0,250	0,245	0,225	0,185	0,115	1,240	1,300	1,360	1,440	1,450	1,450
0,80	0,225	0,225	0,220	0,210	0,180	0,105	1,120	1,200	1,280	1,360	1,420	1,420
1,00	0,205	0,205	0,205	0,200	0,170	0,095	1,040	1,120	1,200	1,300	1,400	1,400

TRANSVERSES												
	B.M. COEFF. K_1						S.F. COEFF. K_2					
β	α						α					
	0,0	0,2	0,4	0,6	0,8	1,0	0,0	0,2	0,4	0,6	0,8	1,0
0,02	0,009	0,008	0,007	0,006	0,005	0,004	0,150	0,145	0,140	0,135	0,130	0,125
0,04	0,011	0,010	0,009	0,008	0,007	0,006	0,162	0,157	0,153	0,148	0,143	0,138
0,06	0,013	0,012	0,011	0,010	0,009	0,008	0,175	0,170	0,163	0,158	0,150	0,147
0,08	0,015	0,014	0,013	0,012	0,011	0,010	0,185	0,180	0,170	0,165	0,157	0,155
0,10	0,017	0,016	0,015	0,014	0,013	0,011	0,192	0,187	0,180	0,175	0,165	0,160
0,20	0,025	0,024	0,023	0,021	0,018	0,017	0,230	0,225	0,220	0,210	0,195	0,185
0,40	0,036	0,035	0,034	0,031	0,027	0,024	0,285	0,275	0,270	0,257	0,237	0,220
0,60	0,045	0,044	0,043	0,038	0,033	0,029	0,325	0,315	0,305	0,290	0,267	0,247
0,80	0,051	0,050	0,048	0,043	0,038	0,033	0,355	0,345	0,330	0,317	0,290	0,270
1,00	0,056	0,055	0,052	0,047	0,043	0,036	0,380	0,370	0,355	0,340	0,310	0,287

TABLE D 46.1—*continued*

(c) 3 GIRDERS 4 TRANSVERSES

GIRDERS												
	B.M. COEFF. K_1						S.F. COEFF. K_2					
β	α						α					
	0,0	0,2	0,4	0,6	0,8	1,0	0,0	0,2	0,4	0,6	0,8	1,0
0,02	0,435	0,435	0,390	0,355	0,315	0,250	2,160	2,160	2,160	2,160	2,160	2,160
0,04	0,435	0,435	0,390	0,355	0,315	0,250	2,160	2,160	2,160	2,160	2,160	2,160
0,06	0,435	0,435	0,390	0,355	0,315	0,250	2,160	2,160	2,160	2,160	2,160	2,160
0,08	0,435	0,435	0,390	0,355	0,315	0,250	2,150	2,160	2,160	2,160	2,160	2,160
0,10	0,433	0,433	0,385	0,355	0,305	0,245	2,130	2,150	2,150	2,160	2,160	2,160
0,20	0,395	0,395	0,365	0,335	0,295	0,235	1,980	2,040	2,050	2,060	2,080	2,100
0,40	0,340	0,340	0,325	0,300	0,265	0,210	1,740	1,800	1,860	1,860	1,920	1,970
0,60	0,300	0,300	0,290	0,275	0,245	0,190	1,580	1,630	1,710	1,760	1,840	1,870
0,80	0,265	0,265	0,265	0,255	0,225	0,175	1,400	1,470	1,580	1,680	1,760	1,800
1,00	0,240	0,240	0,240	0,240	0,210	0,160	1,280	1,360	1,480	1,620	1,700	1,740

TRANSVERSES												
	B.M. COEFF. K_1						S.F. COEFF. K_2					
β	α						α					
	0,0	0,2	0,4	0,6	0,8	1,0	0,0	0,2	0,4	0,6	0,8	1,0
0,02	0,010	0,010	0,010	0,010	0,010	0,010	0,152	0,147	0,142	0,137	0,132	0,127
0,04	0,012	0,011	0,011	0,010	0,010	0,010	0,167	0,160	0,157	0,155	0,150	0,145
0,06	0,014	0,013	0,013	0,012	0,011	0,011	0,180	0,172	0,170	0,165	0,160	0,155
0,08	0,016	0,015	0,014	0,013	0,012	0,012	0,187	0,182	0,180	0,175	0,167	0,160
0,10	0,018	0,017	0,016	0,014	0,014	0,013	0,197	0,192	0,187	0,182	0,175	0,167
0,20	0,027	0,026	0,023	0,022	0,020	0,018	0,242	0,232	0,225	0,215	0,207	0,195
0,40	0,039	0,038	0,035	0,033	0,029	0,025	0,295	0,285	0,275	0,262	0,250	0,235
0,60	0,048	0,046	0,043	0,042	0,035	0,032	0,335	0,325	0,312	0,297	0,280	0,265
0,80	0,054	0,052	0,049	0,045	0,041	0,037	0,370	0,355	0,340	0,325	0,305	0,287
1,00	0,059	0,057	0,053	0,050	0,045	0,041	0,390	0,380	0,362	0,347	0,325	0,305

TABLE D 46.1—*continued*

(c) 3 GIRDERS 5 TRANSVERSES

GIRDERS												
β	B.M. COEFF. K_1						S.F. COEFF. K_2					
	α						α					
	0,0	0,2	0,4	0,6	0,8	1,0	0,0	0,2	0,4	0,6	0,8	1,0
0,02	0,530	0,510	0,475	0,440	0,400	0,345	2,700	2,700	2,700	2,700	2,700	2,700
0,04	0,530	0,510	0,475	0,440	0,400	0,345	2,700	2,700	2,700	2,700	2,700	2,700
0,06	0,525	0,510	0,475	0,440	0,400	0,345	2,680	2,680	2,680	2,680	2,680	2,680
0,08	0,523	0,500	0,475	0,440	0,400	0,345	2,660	2,660	2,660	2,660	2,660	2,680
0,10	0,513	0,495	0,470	0,435	0,395	0,340	2,630	2,630	2,640	2,640	2,650	2,660
0,20	0,465	0,455	0,435	0,410	0,370	0,320	2,440	2,480	2,500	2,520	2,530	2,560
0,40	0,400	0,390	0,380	0,360	0,325	0,280	2,120	2,180	2,240	2,300	2,340	2,370
0,60	0,340	0,340	0,330	0,320	0,290	0,250	1,860	1,960	2,040	2,140	2,180	2,220
0,80	0,305	0,305	0,300	0,290	0,270	0,230	1,660	1,780	1,880	2,000	2,050	2,100
1,00	0,275	0,275	0,275	0,265	0,245	0,210	1,530	1,630	1,750	1,890	1,950	2,000

TRANSVERSES												
β	B.M. COEFF. K_1						S.F. COEFF. K_2					
	α						α					
	0,0	0,2	0,4	0,6	0,8	1,0	0,0	0,2	0,4	0,6	0,8	1,0
0,02	0,005	0,005	0,004	0,004	0,003	0,003	0,150	0,150	0,148	0,146	0,144	0,142
0,04	0,014	0,013	0,013	0,012	0,012	0,011	0,170	0,170	0,167	0,163	0,160	0,157
0,06	0,016	0,015	0,015	0,014	0,014	0,013	0,187	0,187	0,184	0,180	0,177	0,173
0,08	0,019	0,018	0,018	0,017	0,017	0,016	0,205	0,205	0,198	0,194	0,189	0,183
0,10	0,021	0,020	0,020	0,019	0,019	0,018	0,215	0,215	0,207	0,202	0,198	0,193
0,20	0,032	0,030	0,030	0,029	0,028	0,026	0,265	0,265	0,252	0,245	0,239	0,232
0,40	0,045	0,044	0,042	0,041	0,038	0,037	0,325	0,325	0,310	0,300	0,290	0,280
0,60	0,055	0,054	0,051	0,050	0,047	0,045	0,367	0,362	0,350	0,342	0,336	0,330
0,80	0,062	0,060	0,059	0,057	0,054	0,051	0,400	0,400	0,375	0,365	0,355	0,345
1,00	0,067	0,065	0,064	0,064	0,059	0,056	0,420	0,420	0,400	0,387	0,376	0,365

Section 47

SIDE STRINGERS

Symbols

4701

S = span from "span point" to "span point" or from "span point" to side transverse, in metres (feet), (minimum value to be taken as 3 m (9·84 ft)),

b = width of plating supported, in metres (feet). Where applicable, the width supported is to be taken as half the distance from the next stringer to the deck at side or base line as appropriate,

h = head from stringer to highest point of tank, excluding hatchway, in metres (feet).

General

4702 Where transverse side framing is adopted, side stringers are to be fitted as required by D 4503.

Scantlings

4703 The modulus of side stringers is not to be less than given by Table D 47.1:—

TABLE D 47.1

Position of Stringer	Section Modulus Cm^3	Section Modulus In^3
Single	13,55 $b\,h\,S^2$	$\dfrac{b\,h\,S^2}{140}$
Upper of two or more	17,25 $b\,h\,S^2$	$\dfrac{b\,h\,S^2}{110}$
Middle or lower	13,55 $b\,h\,S^2$	$\dfrac{b\,h\,S^2}{140}$

4704 The depth of the stringer is not to be less than 2,5 times the depth of the slot for the frame.

4705 Where side transverses are not fitted the lower side stringers are to be supported by suitable buttress brackets from the bottom transverses.

4706 For minimum thicknesses, *see* D 5309.

For moduli of transverses of various depths, face areas and thicknesses of shell plating, see D 5306.

Section 48

BOTTOM AND DECK GIRDERS

Symbols

4801

L = length of ship, in metres (feet),

D = moulded depth, in metres (feet),

S_G = span of girders, in metres (feet). *See* Fig. D 48.1,

s = spacing of transverses, in metres (feet),

b_t = breadth of tank, measured between faces of the vertical transverses where applicable, in metres (feet),

n = number of continuous longitudinal girders in tank breadth,

m = number of transverses between support bulkheads.

General

4802 The scantling requirements for the bottom girders are given for three basic girder support arrangements (*see* D 4602). Where an arrangement of bottom transverses and girders other than those detailed is proposed this will be specially considered.

Bottom Girders

4803 The section modulus of the girder is not to be less than:—

$$\frac{I}{y} = \frac{62\,K_1\,b_t\,S_G\,D\,s}{(n+1)}\ \text{cm}^3$$

$$\left(\frac{I}{y} = \frac{K_1\,b_t\,S_G\,D\,s}{30\cdot63\,(n+1)}\ \text{in}^3\right)$$

where K_1 = coefficient derived from Table D 46.1. Minimum value of $S_G = s\,(m - 0{,}8)$ metres (feet).

For intercostal centreline docking girder, *see* 4805.

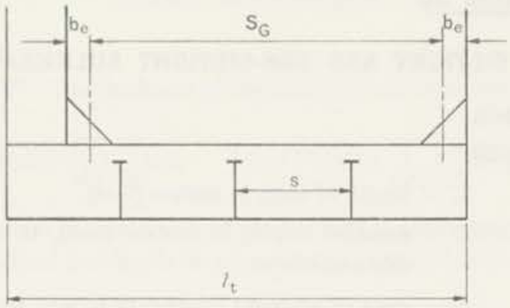
4804 The thickness of the girder web is to be such that the net sectional area of the web at any section in its length is not to be less than:—

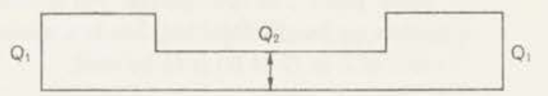
$$A = \frac{Qx}{F}\ \text{cm}^2\ (\text{in}^2)$$

A = net sectional area of the web, including bracket where applicable, in cm^2 (in^2),

Qx = shear force at the actual section under consideration obtained from diagram constructed in accordance with Fig. D 48.1,

F = 0,85 (5·4 British).





$$Q_1 = \frac{1{,}025\ K_2\ D\ s\ b_t}{(n+1)} \text{ tonnes}$$

$$\left(Q_1 = \frac{K_2\ D\ s\ b_t}{35\,(n+1)} \text{ tons}\right)$$

$$Q_2 = Q_1\left(1 - \frac{2}{m}\right)$$

where K_2 = coefficient derived from Table D 46.1,

b_e = effective bracket size, in metres (feet) (*see* Fig. D 46.1).

FIG. D 48.1

Intercostal Bottom Centreline Girder

4805 The section modulus of the girder is not to be less than:—

$$\frac{I}{y} = 3{,}6\ b_t\ D\ s^2 \text{ cm}^3 \qquad \left(\frac{I}{y} = \frac{b_t\ D\ s^2}{526} \text{ in}^3\right)$$

The scantlings of the docking girder may require to be increased depending upon docking condition and support arrangements, details of which are to be submitted.

4806 The depth of an intercostal girder is not to exceed the depth of the transverses.

Continuous or Intercostal Bottom Centreline Girders

4807 Vertical webs are generally to be arranged on the transverse bulkheads in association with bottom centreline girders.

4808 Flanged or otherwise stiffened brackets are to be fitted on both sides of the girder mid-way between the transverses with intermediate vertical stiffeners not more than 990 mm (39 in) apart. The brackets are to be connected to a suitable bottom longitudinal. In deep centreline girders horizontal stiffening is to be arranged and the brackets on one side may stop at a suitable horizontal stiffener. The intermediate vertical stiffeners may be omitted but where the spacing of brackets exceeds 1830 mm (72 in) an intermediate vertical stiffener is to be fitted to the lower part of the girder, or suitable horizontal stiffening is to be arranged.

Continuous Deck Girders

4809 A continuous deck centreline girder is to be fitted having a section modulus not less than:—

$$\frac{I}{y} = \frac{l^2\ b\ L}{10{,}5} \text{ cm}^3 \qquad \left(\frac{I}{y} = \frac{l^2\ b\ L}{20\,000} \text{ in}^3\right)$$

where l = length of centre tank, in metres (feet),

b = half-breadth of centre tank, in metres (feet), or, where there is a vertical web on the inboard side of the longitudinal bulkheads, half the distance between the faces of the webs.

Where continuous side girders are fitted the section modulus of these and the centreline girder is to be derived from the above formula with

$$b = \frac{b_t}{(n+1)}$$

4810 Where intercostal side girders, having scantlings as required by 4811, are fitted in the centre tank the section modulus of the deck centre girder derived in accordance with 4809 may be reduced by 5 per cent.

Intercostal Deck Side Girders

4811 Intercostal side girders are to have a depth not less than 50 per cent of the depth of the deck transverse. The face area is not to be less than that of the transverses.

General

4812 For reduction to modulus of deck centre girder and deck transverses when side girders are fitted, *see* 4810 and D 4613.

4813 For minimum thicknesses, *see* D 5309.

For moduli of girders of various depths, face areas and thicknesses of shell or deck plating, *see* D 5306.

Section 49

CROSS TIES

4901 Cross ties may be of plate or sectional material and are to have an area and least moment of inertia not less than:—

$$A = 64 + 1{,}035\, l\, h\, s \text{ cm}^2$$

$$\left(A = 10 + \frac{l\, h\, s}{220} \text{in}^2\right),$$

$$I = 2{,}45\, l\, h\, s\, S^2 \text{ cm}^4$$

$$\left(I = \frac{l\, h\, s\, S^2}{6500} \text{in}^4\right),$$

where l = one half the distance, in metres (feet), between the centre of the adjacent cross ties or between the centre of the adjacent cross tie and the centre of the bottom or deck transverse,

h = vertical distance, in metres (feet), from the centre of the cross tie to deck at side amidships,

s = spacing of transverses, in metres (feet),

S = length of cross tie, in metres (feet), between the toes of the horizontal tripping brackets on the transverse webs at the cross ties. Special consideration will be given where alternative arrangements omitting the tripping brackets are provided.

Diagonal cross ties will be specially considered but, in general, the area and least moment of inertia of the horizontal cross tie is not to be less than 85 per cent of that required by the above formula assuming the centre cross tie only is fitted. The area of each diagonal cross tie is not to be less than 85 per cent of that required for the horizontal cross tie.

4902 Cross ties are to be connected to the vertical transverses or horizontal girders by suitable brackets. Tripping brackets are to be fitted to the transverses in way of the cross ties and where scallops for longitudinals or frames come in way of the cross ties they are to be closed by plate collars.

4903 Cross ties are to be provided with suitable horizontal stiffening to prevent buckling and twisting. Where the unsupported width of face plate exceeds 150 mm (6 in), additional vertical stiffening is to be arranged to support the face plate.

Section 50

OILTIGHT AND NON-OILTIGHT BULKHEADS

Symbols

5001

L = length of ship, in metres (feet),

D = moulded depth, in metres (feet), to deck at side amidships,

S = span of stiffener, corrugation, web or girder, in metres (feet), measured between girders, girder to "span point" or "span point" to "span point", as appropriate. For horizontal girders on longitudinal bulkheads a minimum value of 3 m (9·84 ft) is to be used,

s = spacing of stiffeners, in mm (in),

h = distance, in metres (feet), from lower edge of plate to highest point of tank, excluding the hatchway,

h_1 = distance, in metres (feet), from centre of span to highest point of tank, excluding the hatchway,

b = width of plating supported, in metres (feet), or as stated otherwise.

OILTIGHT BULKHEADS

General

5002 Longitudinal bulkheads, other than at the centre line, are to be oiltight throughout the cargo tanks and may be plane or horizontally corrugated.

Longitudinal bulkheads may be perforated in pump rooms or cofferdams, provided suitable compensation is arranged.

When a wash bulkhead is fitted, the length or breadth of a tank may, for the purposes of 5016, be measured from the wash bulkhead to the oiltight bulkhead.

5003 Where the ship's side is framed longitudinally the stiffening on the longitudinal bulkheads is to be arranged horizontally. Vertical stiffening may be adopted in association with transverse side framing.

5004 Transverse bulkheads may be plane or with corrugations arranged horizontally or vertically.

5005 The scantlings of cofferdam bulkheads not forming the boundary of a cargo tank are to be as required by D 19 for oil fuel deep tanks.

5006 Beyond the ends of the oil tanks the longitudinal bulkheads are to scarph into the adjoining structure.

PLANE BULKHEADS

Plating

5007 The thickness of the plating is not to be less than

$$t = \left(0{,}31 + \frac{h}{61}\right)\frac{s}{30}\ \text{mm} \qquad \left(t = \left(0{\cdot}31 + \frac{h}{200}\right)\frac{s}{30}\ \text{in}\right),$$

except that the thickness of the top and bottom strakes of longitudinal bulkheads is in no case to be less than:—

$$\text{Top strake } t = \left(0{,}22 + \frac{L}{610}\right)\frac{s}{30}\ \text{mm}$$

$$\left(t = \left(0{\cdot}22 + \frac{L}{2000}\right)\frac{s}{30}\ \text{in}\right),$$

$$\text{Bottom strake } t = \left(0{,}28 + \frac{L}{610}\right)\frac{s}{30}\ \text{mm}$$

$$\left(t = \left(0{\cdot}28 + \frac{L}{2000}\right)\frac{s}{30}\ \text{in}\right).$$

The breadth of the top and bottom strakes of longitudinal bulkhead is not to be less than 0,1D.

For minimum thickness, *see* D 5309.

5008 Where the shear force has to be investigated (*see* D 4104) the thickness of the longitudinal bulkhead plating for 0,5D about mid-depth is to be as required by D 5007, or the following, whichever is the greater:—

$$t = \frac{F\left(0{,}34 - 0{,}075\,\dfrac{A_S}{A_L}\right)}{D\,q}\ \text{mm}$$

$$\left(t = \frac{F\left(0{\cdot}34 - 0{\cdot}075\,\dfrac{A_S}{A_L}\right)}{12\,D\,q}\ \text{in}\right)$$

where F, A_S, A_L and q are as given in D 4307.

Elsewhere, the thickness is not to be less than 90 per cent of that given above.

Stiffeners

5009 The section modulus of horizontal or vertical stiffeners is not to be less than:—

$$\frac{I}{y} = \frac{s\,S^2}{117{,}5}\,(h_1 + 0{,}9)\ \text{cm}^3$$

$$\left(\frac{I}{y} = \frac{s\,S^2}{2680}\,(h_1 + 3)\ \text{in}^3\right).$$

The section modulus given by this formula is that of the stiffener and associated plating. (*See* D 5302.)

5010 The modulus of horizontal stiffeners on longitudinal bulkheads is not to be less than 90 per cent of the modulus of the uppermost side longitudinal. These longitudinals are to comply with the requirements of D 4404.

5011 The modulus of vertical stiffeners on longitudinal or transverse bulkheads may be reduced by 10 per cent where vertical webs are fitted.

5012 Stiffeners are to be bracketed or otherwise efficiently connected at their ends to provide adequate fixity and, for horizontal stiffeners, continuity of longitudinal strength at the bulkheads.

The end brackets of longitudinal bulkhead vertical stiffeners are to be as required by Table D 57.5 and are to be connected to a suitable longitudinal or are to be well hollowed and tapered.

All stiffeners are to be connected to the supporting webs or girders as required by Table D 57.6.

The plating is to be efficiently stiffened to support loads transmitted by end connections of longitudinal bulkhead, shell and deck longitudinals and the like.

Webs and Girders

5013 The section modulus of vertical webs and horizontal girders is not to be less than that required by Table D 50.1

For intercostal vertical webs not supporting stiffeners (item 2 in Table D 50.1) b_1 is to be taken as half the breadth of centre tank (or the breadth of wing tank) divided by the number of webs plus one (number of webs to be those in the half breadth of centre tank or breadth of wing tank as appropriate) and S is to be measured between girders or from girder to span point. The maximum value of $6{,}9\,b_1\,h_1\,S^2$ $\left(\dfrac{b_1\,h_1\,S^2}{275}\ \text{British}\right)$ is to be used for the full depth of bulkhead.

5014 Where the distance between transverse bulkheads (whether oiltight or non-oiltight) exceeds 24,5 m (80 ft), and continuous side girders are not fitted in the centre tank, the centreline vertical web is to be symmetrical on both sides of the transverse bulkhead.

5015 Where webs are symmetrical on each side of a plane bulkhead the section modulus derived as above may be reduced by 10 per cent.

TABLE D 50.1

Item	Section Modulus Cm^3	Section Modulus In^3
1. VERTICAL WEBS (other than in (2) below)		
(a) On transverse bulkheads not forming a ring system but including the web on the centre line.	$12{,}65 b\, h_1\, S^2$	$\frac{b\, h_1\, S^2}{150}$
(b) On transverse bulkheads forming a ring system* (other than at centre line) as primary supporting members and supporting horizontal stiffeners.	$10 b\, h_1\, S^2$	$\frac{b\, h_1\, S^2}{190}$
(c) On longitudinal bulkheads	as for side transverse	as for side transverse
2. INTERCOSTAL VERTICAL WEBS ON TRANSVERSE BULKHEADS NOT SUPPORTING STIFFENERS	$6{,}9 b_1\, h_1\, S^2$	$\frac{b_1\, h_1\, S^2}{275}$
3. HORIZONTAL GIRDERS ON LONGITUDINAL OR TRANSVERSE BULKHEADS		
(a) Single girder	$11{,}9 b\, h_1\, S^2$	$\frac{b\, h_1\, S^2}{160}$
(b) Upper of two or more	$14{,}6 b\, h_1\, S^2$	$\frac{b\, h_1\, S^2}{130}$
(c) Middle or lower	$11{,}9 b\, h_1\, S^2$	$\frac{b\, h_1\, S^2}{160}$

* i.e., in association with bottom and deck girders of Rule scantlings

(*See also* 5014 to 5016).

5016 Where the breadth of a cargo tank exceeds 14 m (46 ft) the section modulus of the horizontal girders on the longitudinal bulkhead is to be increased at the rate of 2 per cent 0,3 m (1 ft) excess above 14 m (46 ft).

5017 Where side transverses are required by D 4504, vertical webs are to be fitted on the longitudinal bulkhead. Where vertical webs are not fitted, the lower horizontal girders are to be supported by suitable buttress brackets from thebottom transverses.

5018 The depth of a girder or web is not to be less than 2,5 times the depth of the slot for the stiffener.

For minimum thicknesses, *see* D 5309.

For moduli of webs and girders of various depths, face areas and bulkhead plating, *see* D 5306.

5019 The end attachments of vertical webs and horizontal girders are to have a length of arm at least equal to the depth of web.

CORRUGATED BULKHEADS

General

5020 Where corrugated bulkheads are adopted the corrugations should be arranged in accordance with 5002 and 5004.

5021 In ships above 180 m (590 ft) in length the upper and lower strakes of the longitudinal bulkhead are to be plane for a distance of 0,1D from the deck and bottom and the vertical webs are to be arranged symmetrically on each side of the longitudinal bulkhead. Alternative arrangements with unsymmetrical webs will be specially considered, having in view the spacing of transverses and the type of transverse bulkhead, etc.

Plating

5022 The thickness of the plating is not to be less than

$$t = \left(0{,}31 + \frac{h}{61}\right)\frac{s_1}{30}\ \text{mm}$$

$$\left(t = \left(0{\cdot}31 + \frac{h}{200}\right)\frac{s_1}{30}\ \text{in}\right),$$

where s_1 = width of panel, in mm (in), (flat or inclined surface, i.e., b or c in Fig. D 50.1, whichever is the greater). A minimum value of 610 (24 British) is to be used in this formula.

When s_1 exceeds 840 mm (33 in) the scantlings will be specially considered.

The thickness of the top and bottom strakes of longitudinal bulkheads is to be not less than required by 5007.

The thickness of plating is also to be such that the requirements of 5023 are satisfied.

For minimum thickness, *see* D 5309.

5023 The minimum angle of corrugation is to be 40° and the dimensions of the corrugations are to fulfil the following conditions:—

$$\frac{t\ d\ (3\ b+c)}{59\ p} \text{ not to be less than } h_1\ S_1^2 \quad (1)$$

$$\frac{t\ d^2\ (3\ b+c)}{3800\ p} \text{ not to be less than } h_1\ S_1^3 \quad (2)$$

or in British units:—

$$\frac{t\ d\ (3\ b+c)}{p} \text{ not to be less than } \frac{h_1\ S_1^2}{385} \quad (1)$$

$$\frac{t\ d^2\ (3\ b+c)}{p} \text{ not to be less than } \frac{h_1\ S_1^3}{500} \quad (2)$$

where S_1 = span of corrugation, in metres (feet), measured from girder to girder, transverse to transverse or side, bottom, deck or bulkhead to transverse or girder,

and t, b, c, d and p in mm (in) are as shown in Fig. D 50.1 below.

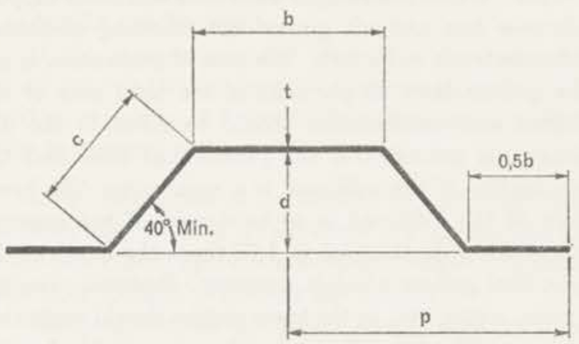


Fig. D 50.1

In (1) and (2) above the value of b is not to be taken as greater than 50 t. Where unsymmetrical girders or webs are fitted to corrugated bulkheads, the maximum angle of corrugation is to be 60°.

5024 Where the shear force has to be investigated (*see* D 4104) the thickness of the longitudinal bulkhead plating is to be as required by 5022 and 5023 or 5008 whichever is the greater.

5025 Corrugations are to be in line, and of the same form, on each side of bulkheads, horizontal girders and vertical webs.

Webs and Girders

5026 Horizontal girders and vertical webs are to be arranged to support the corrugations. The spacing of transverses on longitudinal bulkheads is generally not to exceed 5 m (16·5 ft).

5027 The section modulus of vertical webs and horizontal girders is not to be less than that required by Table D 50.2.

For vertical webs forming a ring system and not supporting girders, b_1 is to be taken as half the breadth of the centre tank (or breadth of wing tank) divided by the number of webs plus one and S is to be measured between girders or from girder to span point. The maximum value of $6{,}9\,b_1\,h_1\,S^2$ $\left(\frac{b_1 h_1 S^2}{275}\text{ British}\right)$ is to be used for the full depth of bulkhead.

TABLE D 50.2

Item	Section Modulus Cm³	Section Modulus In³
1. VERTICAL WEBS		
(a) ON VERTICALLY CORRUGATED BULKHEADS		
At centreline	$12{,}65b\,h_1\,S^2$	$\frac{b\,h_1\,S^2}{150}$
Other webs forming a ring system* and not supporting girders	$6{,}9b_1\,h_1\,S^2$	$\frac{b_1\,h_1\,S^2}{275}$
(b) ON HORIZONTALLY CORRUGATED BULKHEADS		
(i) Transverse bulkheads: At centre line	$12{,}65b\,h_1\,S^2$	$\frac{b\,h_1\,S^2}{150}$
Other webs forming a ring system*	$10b\,h_1\,S^2$	$\frac{b\,h_1\,S^2}{190}$
Webs not forming a ring system	$12{,}65b\,h_1\,S^2$	$\frac{b\,h_1\,S^2}{150}$
(ii) Longitudinal bulkheads	as for side transverse	as for side transverse
2. HORIZONTAL GIRDERS ON VERTICALLY CORRUGATED TRANSVERSE BULKHEADS		
(a) Single girder	$11{,}9b\,h_1\,S^2$	$\frac{b\,h_1\,S^2}{160}$
(b) Upper of two or more	$14{,}6b\,h_1\,S^2$	$\frac{b\,h_1\,S^2}{130}$
(c) Middle or lower	$11{,}9b\,h_1\,S^2$	$\frac{b\,h_1\,S^2}{160}$

* i.e., in association with bottom and deck girders of Rule scantlings. (*See also* 5028 and 5029)

5028 Where the distance between transverse bulkheads (whether oiltight or non-oiltight) exceeds 25 m (82 ft), and continuous side girders are not fitted in the centre tank, the centreline vertical web is to be symmetrical on both sides of the transverse bulkhead.

5029 Where webs or girders are symmetrical on each side of a corrugated bulkhead the section modulus derived as above may be reduced by 10 per cent.

5030 For minimum thickness, *see* D 5309.

For moduli of webs and girders of various depths, face areas and bulkhead plating, *see* D 5306.

5031 The end attachments of vertical webs and horizontal girders are to have a length of arm at least equal to the depth of web.

NON-OILTIGHT BULKHEADS (PLANE OR CORRUGATED)

General

5032 Wash bulkheads and perforated centreline longitudinal bulkheads are to have an area of perforations not

less than 10 per cent of the total area of the bulkhead. The perforations are to be so arranged that the bulkheads act as an efficient girder, web or transverse and the lower part of a centreline bulkhead is to be adequately stiffened to act as a docking girder. (*See also* 5038.)

Where no continuous girders are fitted, consideration will be given to the omission of complete wash bulkheads provided suitable deep deck transverses are arranged.

Special care is to be taken to ensure that a perforated centreline longitudinal bulkhead provides an efficient connection between the deck and bottom plating.

Plating

5033 The thickness of plating may be the compartment minimum (*see* D 5309) except that the top and bottom strakes of a centreline bulkhead are to be as required by 5007 for an oiltight longitudinal bulkhead. (*See also* 5038.)

Stiffeners, Girders and Webs

5034 The section modulus of stiffeners and horizontal girders is to be not less than:—

$$\frac{I}{y} = k\, s_1 S^2 \frac{l}{L} \text{ cm}^3 \qquad \left(\frac{I}{y} = k\, s_1 S^2 \frac{l}{L} 10^{-4}\text{in}\right),$$

where $k = 1215 \times 10^{-4}$ (175 British) for stiffeners on transverse bulkheads,

3785×10^{-4} (545 British) for stiffeners on longitudinal bulkheads,

145 (2520 British) for girders on transverse bulkheads,

452 (7820 British) for girders on longitudinal bulkheads,

s_1 = spacing of stiffeners, in mm (in), or width of plating supported by girder, in metres (feet),

l = length or breadth, in metres (feet), of tank between oiltight bulkheads for transverse or longitudinal bulkheads respectively. Where two or more transverse wash bulkheads are fitted in one tank l is to be measured between the bulkheads adjacent to the wash bulkhead under consideration.

5035 The section modulus of vertical webs is to be not less than:—

On transverse bulkheads—the modulus required for an oiltight bulkhead multiplied by $\left(0{,}3 + 2\frac{l}{L}\right)$ where l is as defined in 5034.

On longitudinal bulkheads—50 per cent of that required for an oiltight bulkhead.

5036 The depth of webs and girders is to be at least 2,5 times the depth of the slot for the stiffener.

5037 When determining the width of plating supported and the effective area for calculating the modulus no deduction is to be made on account of perforations.

5038 Where non-oiltight transverse bulkheads support continuous fore and aft girders the following additional requirements are to be met. The area of perforation is not to be greater than 25 per cent of the total area of the bulkhead and consideration should be given to the disposition and geometry of the perforations such that the shear rigidity of the bulkhead is a maximum. The lower section of the bulkhead is to be devoid of non-essential openings for a depth equal to 1,75 times the depth of the longitudinal girders which it supports. Essential openings for pipes, access, etc., in the lower section should preferably be circular with edge stiffening or otherwise suitably framed.

The net sectional area of the bulkhead is not to be less than:—

$$A = \frac{n\, l_b\, b_t\, D}{1{,}85\,(n+1)} \text{ cm}^2 \qquad \left(A = \frac{n\, l_b\, b_t\, D}{420\,(n+1)} \text{ in}^2\right)$$

where l_b = half the distance between adjacent transverse support bulkheads forward and aft of the wash bulkhead under consideration, in metres (feet),

n = number of longitudinal continuous girders supported by bulkhead,

b_t = breadth of tank, in metres (feet).

The thickness of the plating may not be less than:—

$$t = \frac{a}{100 + 33\dfrac{a}{b}} \text{ cm (in)}$$

where a = least dimension of unstiffened plate panel, in cm (in),

b = greatest dimension of unstiffened plate panel in cm (in).

In no case should either panel dimension exceed 180t or that given by 5033.

Section 51

HATCHWAYS

Oiltight Hatchways

5101 Oiltight hatchways are to be kept to the minimum size required to provide reasonable access and ventilation to each compartment.

Corners of hatchway openings are to be well rounded and smooth.

5102 The height of the coaming is not to be less than 250 mm (9·84 in). Coaming plates not exceeding 820 mm (32 in) in height are not to be less than 10 mm (0·40 in) in thickness.

5103 Where the area of the hatchway cover does not exceed 1,2 m^2 (13 ft^2) in a circular hatchway, or 1,5 m^2 (16 ft^2) in a rectangular hatchway, the thickness of the cover is to be 12,5 mm (0·50 in).

If the area exceeds the above but does not exceed 2,4 m^2 (26 ft^2) the thickness of the cover is to be 15 mm (0·60 in) or may be 12,5 mm (0·50 in) if stiffened by 100 mm (4 in) flats spaced 610 mm (24 in) apart.

5104 Covers are to be secured by fastenings spaced not more than 457 mm (18 in) apart in a circular hatchway or 380 mm (15 in) apart in a rectangular hatchway and not more than 230 mm (9 in) from the corners.

Hatchway covers of special design with alternative methods of closing will be specially considered.

Ullage Plugs and Tank Cleaning Openings

5105 Ullage plugs, sighting ports and tank cleaning openings are not to be arranged in enclosed spaces.

Access to Cofferdams, Dry Tanks or Water Ballast Tanks

5106 If hatchways are provided for access to these spaces the requirements of 5101 to 5104 are to be complied with.

5107 Access may be by a watertight manhole provided the plate cover is not less than 12,5 mm (0·50 in) in thickness and the bolts are not more than 100 mm (4 in) apart.

Hatchways to Spaces other than Oil Tanks, Cofferdams, Dry Tanks, or Water Ballast Tanks

5108 Hatchways are to be constructed in accordance with the requirements of D 26 except that efficient steel watertight covers are to be fitted to hatchways situated on expansion trunks and on the strength deck, either where exposed or inside open superstructures.

Hatchways situated on the forecastle deck are to have steel covers except where efficient steel watertight covers are fitted to the hatchways inside the forecastle.

Section 52

TESTING

General

5201 Each cargo tank and cofferdam is to be separately tested by filling with water to the test head.

When water testing on the building berth or in dry dock may be undesirable, testing may be carried out afloat, provided any riveted shell seams in the bottom and bilge plating are tested with a high pressure hose test on the berth. The testing afloat is to be carried out by separately filling each tank and cofferdam to the test head. With about half the number of tanks full, the bottom and lower side shell in the empty tanks is to be examined and the remainder of the bottom and lower side shell examined when the water is transferred.

When a preservative coating is to be applied to the internal structure of a tank, the water testing may take place after the application of the preservative, provided the structure is carefully examined to ensure that all welding and structural stiffening is completed prior to the application of the coating and any riveted shell seams are tested with a high pressure hose test on the berth before coating. The hose test of the riveted seams may be carried out from the outside to avoid wetting the tank structure.

The cause of any discoloration or disturbance of the coating is to be ascertained and any deficiencies repaired.

5202 In lieu of the complete water testing required by 5201 a combination of a leak test and a structural test may be adopted.

The leak test is to be carried out on each tank while the vessel is on the building berth; it is to consist of a soapy solution test made while the tank is subjected to an air pressure of 0,14 kg/cm^2 (2 lb/in^2). It is recommended that the air pressure in the tank be raised to 0,21 kg/cm^2 (3 lb/in^2) with the minimum number of personnel in the vicinity of the tank and lowered to the test pressure before inspection commences.

A structural test is to be applied to one centre and two side tanks (to be selected by the Surveyor) by water testing to the test head (*see* 5205).

Air testing is to be carried out before a protective coating is applied.

5203 Water ballast and dry tanks should be tested as required for cargo tanks.

5204 It is recommended that pump rooms be flooded to a suitable depth prior to launch. The bottom and side shell plating is to be carefully examined internally with the vessel at a deep draught. Bulkheads not forming tank boundaries are to be hose tested.

Test Head

5205 The test head for cargo tanks is to be 2,45 m (8 ft) above the highest point of the tank, excluding hatchways; that for cofferdams is to be to the top of the hatchway.

Bunkers and Deep Tanks

5206 Bunkers and deep tanks are to be tested as required by D 1931.

Section 53

EFFECTIVE SECTION MODULUS, FACE AREAS AND MINIMUM THICKNESSES

Symbols

5301

L = length of ship, in metres (feet),

d = depth of girder, etc., in mm (in), between inside of face plate and attached plating or for symmetrical girders between inside of face plates. Where a girder, etc., is at right angles to a line of corrugations the minimum depth is to be taken,

t_p = mean thickness of attached shell, deck or bulkhead plating, in mm (in),

t_w = thickness of web, in mm (in).

EFFECTIVE SECTION MODULUS

Longitudinals, Frames and Stiffeners

5302 For longitudinals, side frames and bulkhead stiffeners the section modulus required by the appropriate formula is to be that of the section in association with 610 mm (24 in) of plating having the same thickness as the shell, deck or bulkhead plating as appropriate. Where the attached plating is of varying thickness, the mean thickness over the appropriate span is to be used.

The effective section moduli of rolled sections and the area of the section without plating are given in the publication "Geometric Properties of Rolled Sections and Built Girders".

The effective section moduli of flat bars or built sections may be obtained from curves in the above publication.

Transverses, Webs, Stringers and Girders

5303 For transverses, webs, stringers and girders, the section modulus required by the appropriate formula is to be that of the member in association with an effective area of shell, deck or bulkhead plating.

5304 Except for corrugated bulkheads, the effective area is to be:—

$$A = 10\,k\,b\,t_p \text{ cm}^2 \quad (A = 12\,k\,b\,t_p \text{ in}^2),$$

where k = a coefficient obtained from Table D 53.1,

b = actual width, in metres (feet), of load-bearing plating, i.e., one half the sum of spacings of parallel adjacent members of greater or equivalent length (*see* Fig. D 53.1),

l = overall length of girder, transverse, etc., in metres (feet) (*see* Fig. D 53.1).

TABLE D 53.1

$\frac{l}{b}$	0,5	1,0	2,0	3,0	4,0	5,0	6,0
k	0,12	0,23	0,45	0,67	0,80	0,90	1,00

For intermediate values of $\frac{l}{b}$, k is to be obtained by interpolation. Where $\frac{l}{b}$ exceeds 6,0, k is to be taken as 1,0.

5305 For corrugated bulkheads the effective area is to be:—

(a) for girders, etc., at right angles to the direction of corrugations:

A = area of face plate in cm² (in²) (*see also* 5308),

(b) for girders, etc., parallel to the direction of corrugations:

$$A = \frac{b_c\,t_p}{100} \text{ cm}^2 \quad (A = b_c\,t_p \text{ in}^2),$$

where b_c = breadth, in mm (in), of flat panel of corrugated bulkhead.

5306 The effective section modulus of any transverse, web, stringer or girder is given by:—

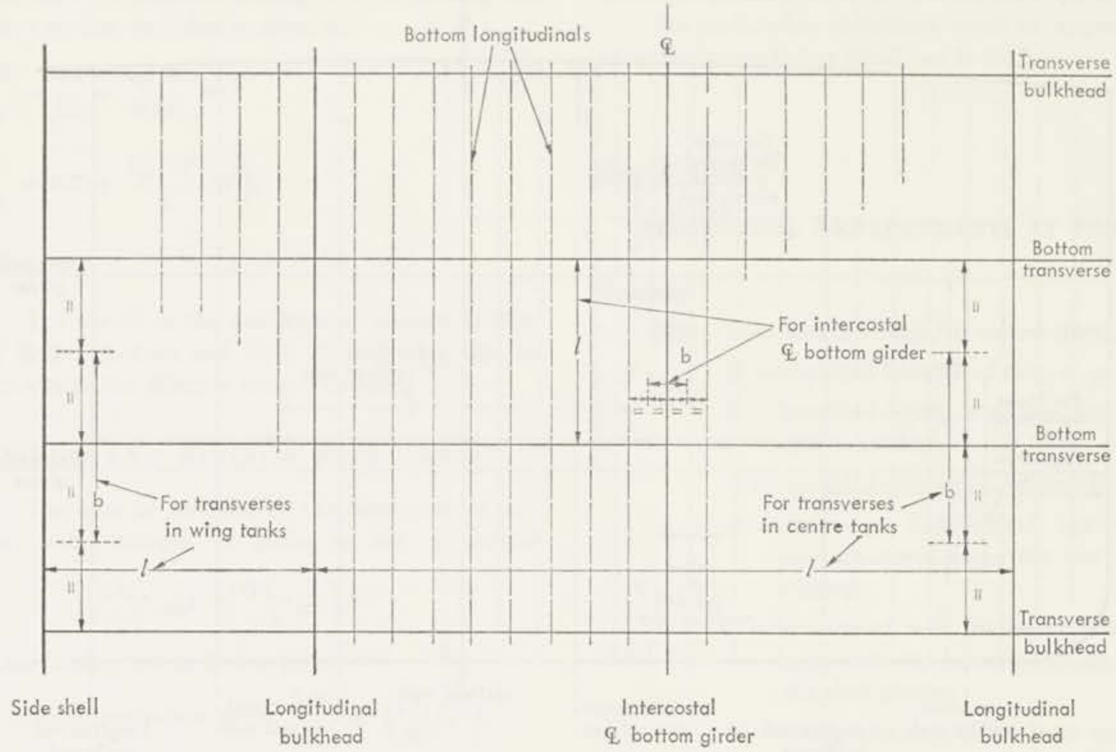
$$\frac{I}{y} = \frac{ad}{10} + \frac{t_w d^2}{6000}\left[1 + \frac{200\,(A - a)}{200\,A + t_w d}\right] \text{cm}^3 \quad (1)$$

$$\left(\frac{I}{y} = ad + \frac{t_w d^2}{6}\left[1 + \frac{A - a}{A + 0{\cdot}5\,t_w d}\right] \text{in}^3\right),$$

where a = area of face plate, in cm² (in²).

Where the effective area A derived in accordance with 5304 or 5305 is less than the face area, A is to be taken as equal to a.

(a) BOTTOM STRUCTURE WITH INTERCOSTAL BOTTOM CENTRE-LINE GIRDER



(b) BOTTOM STRUCTURE WITH CONTINUOUS BOTTOM CENTRE-LINE GIRDER

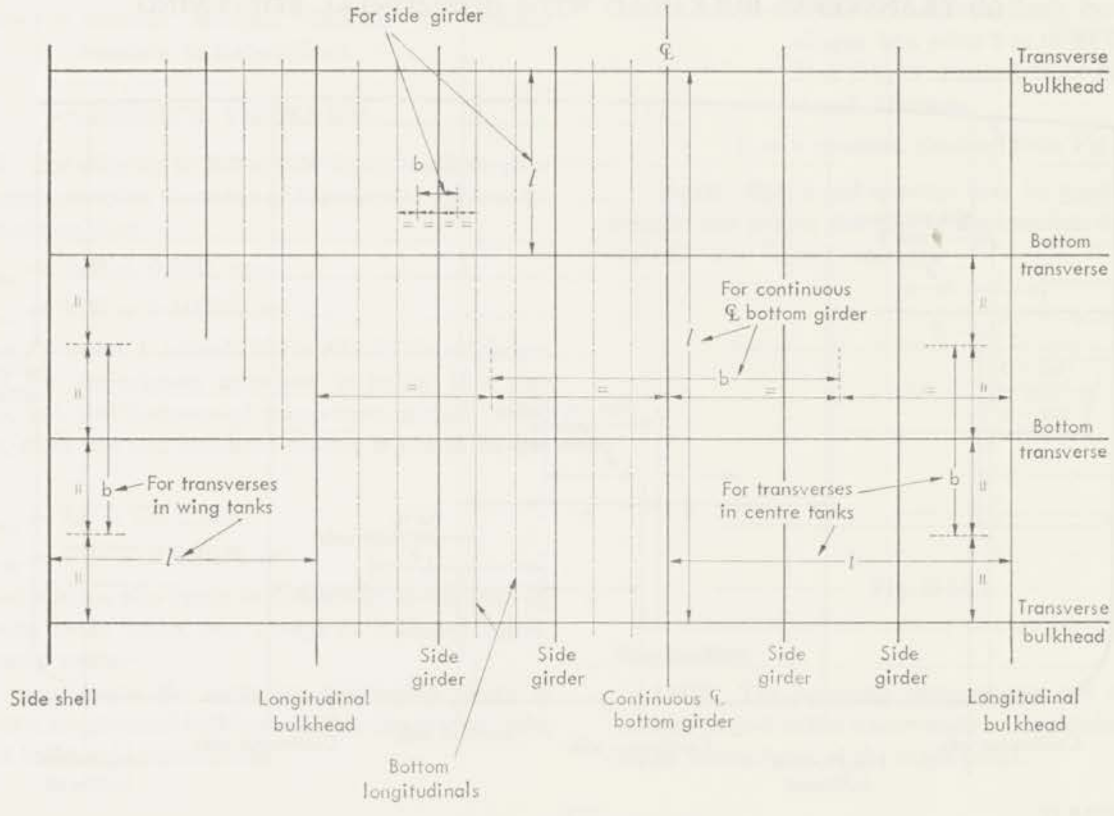
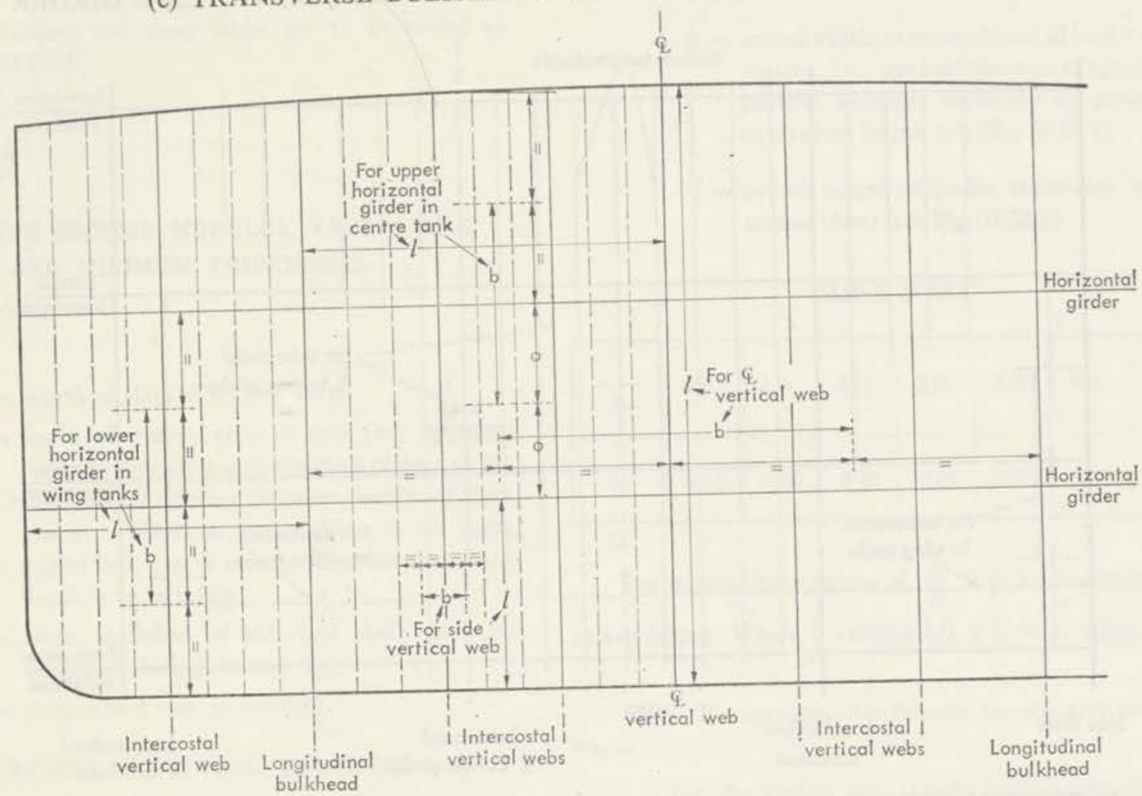


FIG. D 53.1 (*see continuation*)

(c) TRANSVERSE BULKHEAD WITH VERTICAL STIFFENING



(d) TRANSVERSE BULKHEAD WITH HORIZONTAL STIFFENING

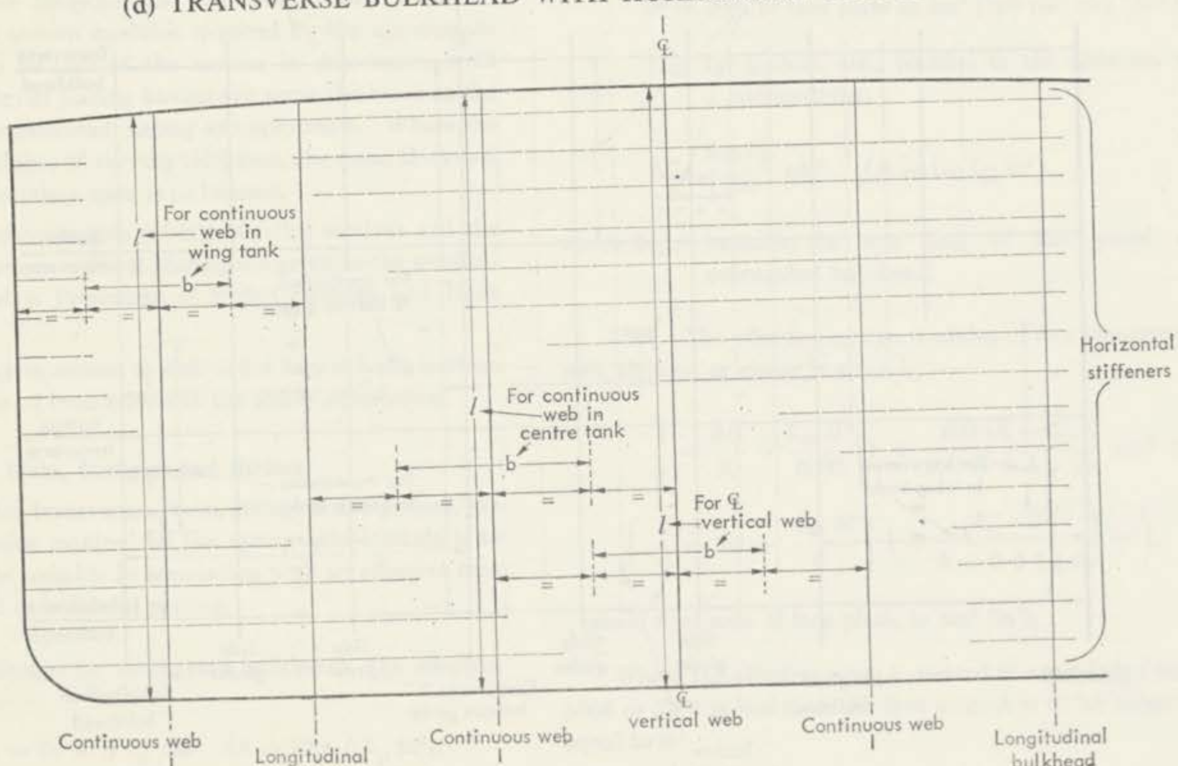


Fig. D 53.1 (*concluded*)

For girders, etc., which are symmetrical on each side of the bulkhead the attached plating is to be ignored and the effective section modulus is given by:—

$$\frac{I}{y} = \frac{ad}{10} + \frac{t_w\, d^2}{6000}\ \mathrm{cm}^3 \qquad (2)$$

$$\left(\frac{I}{y} = ad + \frac{t_w\ d^2}{6}\ \mathrm{in}^3\right),$$

where a = area of one face plate in cm² (in²).

5307 The curves in the publication "Geometric Properties of Rolled Sections and Built Girders" may also be used to determine the effective section modulus.

MAXIMUM AND MINIMUM FACE AREAS

5308 The area of material in the face plate of any transverse, web, stringer or girder is not to exceed

$$\frac{d\,t_w}{150}\ \mathrm{cm}^2 \quad \left(\frac{d\,t_w}{1{\cdot}5}\ \mathrm{in}^2\right).$$

The face area is not to be less than:—

(a) bottom centreline girder $\frac{l\,d}{60}$ cm² $\left(\frac{l\,d}{50}\ \mathrm{in}^2\right)$

(b) other transverses, girders, etc., $\frac{l\,d}{240}$ cm² $\left(\frac{l\,d}{200}\ \mathrm{in}^2\right)$

where l = distance between docking or tripping brackets, in metres (feet).

MINIMUM THICKNESS

5309 For ships up to 200 m (656 ft) in length no part of the structure within the range of the cargo tanks is to be less in thickness than:—

$t_{min} = 6{,}85 + 0{,}024L$ mm

$(t_{min} = 0{\cdot}27 + 0{\cdot}00029L$ in)

When, however, L exceeds 200 m (656 ft) the minimum thickness for non-primary members is to be 11,5 mm (0·46 in), but the thickness of transverses, girders, webs, stringers, cross ties and bulkhead plating is not to be less than:—

$t_{min} = 9{,}5 + 0{,}01L$ mm

$(t_{min} = 0{\cdot}38 + 0{\cdot}00012L$ in)

These minima also apply to cofferdams at the ends of, or between, cargo tanks, but, except as indicated below, not to pump rooms.

In pump rooms the minimum thicknesses apply to shell, decks, longitudinal bulkheads and to the bottom, side, deck and bulkhead longitudinals.

For other items solely within these spaces the minimum derived from the formulæ may be reduced by 1 mm (0·04 in).

For permissible reductions when an approved system of corrosion control is fitted, see D 4016.

Section 54

STRUCTURAL ARRANGEMENTS AT FORE END

Symbols

5401 L = length of ship, in metres (feet).

B = moulded breadth of ship, in metres (feet).

D = moulded depth, in metres (feet), to deck at side amidships.

d = moulded draught, in metres (feet).

s = frame or longitudinal spacing, in mm (in), measured along the line of the shell plating.

s_1 = spacing of web frames or transverses, in metres (feet), measured along the line of the shell plating.

S = span, in metres (feet), from span point to span point, measured along the line of the shell plating.

h = distance, in metres (feet), from mid-point of span to a point 3 m (9·84 ft) above the deck height obtained from D 1702 unless stated otherwise.

C = a constant obtained from Fig. D 54.1.

NOTE.—Spans and spacings may be measured along a straight line joining the ends of the member. Slopes smaller than 10° may be ignored.

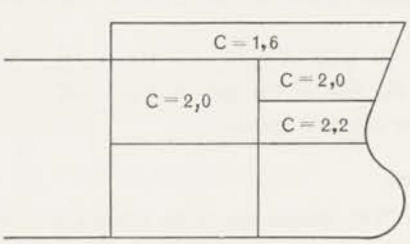


Fig. D 54.1

Construction

5402 The following requirements are applicable to tankers framed either transversely or longitudinally forward of the forward end of the cargo tanks.

If a combination of transverse and longitudinal framing is adopted equivalent strength is to be provided.

A centreline bulkhead, which may be non-oiltight, is to be fitted in the deep tank, or the longitudinal bulkheads are to extend forward to the forward deep tank bulkhead.

TRANSVERSE FRAMING SYSTEM

CONSTRUCTION IN WAY OF DEEP TANKS

Frame Spacing

5403 The frame spacing in deep tanks is not, in general, to exceed 700 mm (27·5 in) where D is greater than 8,9 m (29ft) and $\frac{1000D}{24} + 330\,\text{mm}$ $\left(\frac{D}{2} + 13\,\text{in}\right)$ where D is less than 8,9 m (29 ft).

Bottom Construction

5404 Floors are to be fitted at every frame. They are to have a minimum depth at the centreline of:—

$$\frac{1000D}{12} + 150\ \text{mm} \qquad (D + 6\ \text{in})$$

and a thickness of not less than:—

$$t = 0{,}666D + 2\ \text{mm} \qquad (t = 0{\cdot}008\,D + 0{\cdot}08\ \text{in})$$

but the thickness of the floors need not exceed 11,5 mm (0·46 in), and the depth of the floors need not exceed 1400 mm (55 in), but *see also* 5406.

Floors are to be adequately stiffened and the area of the face bar on the upper edge of the floors is not to be less than:—

$$\frac{B}{1{,}18}\ \text{cm}^2 \qquad \left(\frac{B}{25}\ \text{in}^2\right).$$

5405 Intercostal side girders are to be fitted between the floors, in line with alternate bottom longitudinals in the forward cargo tanks, and are to be extended as far forward as practicable. They are to have the same depth as the floors.

5406 In way of side web frames the depth of the floor and the size of the face bar are not to be less than required for the web frame.

Web Frames

5407 Web frames are to be fitted not more than five frame spaces apart and are to have a section modulus not less than:—

$$\frac{I}{y} = 9\ s_1\ h\ S^2\ \text{cm}^3 \qquad \left(\frac{I}{y} = \frac{s_1\ h\ S^2}{210}\ \text{in}^3\right)$$

but h is not to be taken as less than the distance from the mid-point of span to the highest point of the tank, excluding the hatchway.

Side Stringers

5408 Horizontal side stringers are to be arranged in the deep tank in line with the stringers in the fore peak and are to have section moduli not less than:—

(1) supporting stringers which are to be in line with alternate fore peak stringers:—

$$\frac{I}{y} = 33{,}2\ h\ s_1^2\ \text{cm}^3 \qquad \left(\frac{I}{y} = \frac{h\ s_1^2}{17{\cdot}5}\ \text{in}^3\right)$$

and (2) intermediate stringers:—

$$\frac{I}{y} = 23{,}3\ h\ s_1^2\ \text{cm}^3 \qquad \left(\frac{I}{y} = \frac{h\ s_1^2}{25}\ \text{in}^3\right)$$

but h is not to be taken as less than the distance from the stringer to the highest point of the tank, excluding the hatchway.

Side Framing

5409 Deep tank side frames are to be determined in accordance with D 721 with H measured between the supporting stringers, *see* 5408(1).

Deep Tanks Extending to Uppermost Continuous Deck

5410 For additional requirements when deep tanks extend to the uppermost continuous deck, *see* 5439.

CONSTRUCTION IN DRY CARGO HOLD ABOVE DEEP TANKS

Web Frames

5411 Web frames are to be fitted in the dry cargo hold in line with those in the deep tank below and are to have a section modulus not less than:—

$$\frac{I}{y} = 1{,}68\ C\ s_1\ h_1\ d\ \sqrt{D}\ \text{cm}^3$$

$$\left(\frac{I}{y} = \frac{C\ s_1\ h_1\ d\ \sqrt{D}}{625}\ \text{in}^3\right)$$

where h_1 = 'tween deck height, in metres (feet).

Side Stringers

5412 Side stringers are to be fitted in dry cargo holds, spaced about 2,5 m (8·2 ft) apart and are to have the same depth as the frame. The minimum thickness of the intercostal plate web is to be 8,5 mm (0·34 in) and the area of the face plate is to be:—

$$\frac{L}{7} + 6\ \text{cm}^2 \qquad \left(\frac{L}{150} + 1\ \text{in}^2\right)$$

Framing

5413 Frames in dry cargo holds above deep tanks are to be determined in accordance with D 707 but ignoring the panting factor "f" in Fig. D 7.3.

CONSTRUCTION IN FORE PEAKS

Framing

5414 The frames in the fore peak are generally to be spaced 610 mm (24 in) apart and are to be determined in accordance with D 713 and to have a vertical extent not less than required by Fig. D 7.3.

Floors

5415 Floors are to be fitted at every frame, and are to have a depth and thickness not less than required by 5404, and their free edges are to be suitably stiffened.

Panting Beams

5416 Tiers of panting beams are to be fitted on alternate frames in the fore peak, spaced not more than 2,0 m (6·56 ft) apart. They are to have scantlings in accordance with D 1103.

5417 If desired, an arrangement incorporating perforated flats in lieu of tiers of panting beams may be adopted. These may be spaced 2,5 m (8·2 ft) apart and are to have scantlings as required by 5439(1).

Side Stringers

5418 Side stringers determined in accordance with D 1106 are to be fitted at each tier of panting beams.

'Tween Decks Above Fore Peaks

5419 Frames in 'tween decks above fore peaks are to be determined in accordance with D 707.

LONGITUDINAL FRAMING SYSTEM

CONSTRUCTION IN WAY OF DEEP TANKS

Bottom Transverses

5420 Bottom transverses in deep tanks are to be spaced not more than 3 m (9·84 ft) apart and are to have a section modulus in accordance with D 4603.

Bottom Longitudinals

5421 Bottom longitudinals are to be fitted in line with those in the cargo tanks and are to have a section modulus in accordance with D 4402.

Side Girders

5422 An intercostal side girder, which is to have the same depth as the bottom transverses, is to be fitted each side of the centreline.

Centreline Girder

5423 Where the cargo tank longitudinal bulkheads are extended forward into the deep tanks and the centreline bulkhead is omitted, a centre girder having a section modulus in accordance with D 4805 is to be fitted.

Side Transverses

5424 Side transverses are to be spaced not more than 3,0 m (9·84 ft) apart and are to have a section modulus not less than:—

$$\frac{I}{y} = 9\, s_1\, h\, S^2 \text{ cm}^3 \qquad \left(\frac{I}{y} = \frac{s_1\, h\, S^2}{210} \text{ in}^3\right)$$

Side transverses are to be in line with forecastle deck transverses.

Side Longitudinals

5425 The section modulus of the side longitudinals is not to be less than given by the following formula, or by D 4402, whichever is the greater:—

$$\frac{I}{y} = \frac{s\, h\, S^2}{132} \text{ cm}^3 \qquad \left(\frac{I}{y} = \frac{s\, h\, S^2}{3000} \text{ in}^3\right)$$

Deep Tank Extending to Uppermost Continuous Deck

5426 For additional requirements when deep tanks extend to the uppermost continuous deck, *see* 5439.

CONSTRUCTION IN DRY CARGO HOLDS ABOVE DEEP TANKS

Side Transverses

5427 Side transverses in the dry cargo hold are to be in line with those in the deep tank below and are to have a section modulus not less than:—

$$\frac{I}{y} = 2{,}3\, C\, s_1\, h_1\, d\, \sqrt{D} \text{ cm}^3$$

$$\left(\frac{I}{y} = \frac{C\, s_1\, h_1\, d\, \sqrt{D}}{450} \text{ in}^3\right)$$

where h_1 = 'tween deck height, in metres (feet).

Side Longitudinals

5428 The section modulus of side longitudinals in cargo holds above deep tanks is to be in accordance with 5425.

CONSTRUCTION IN FORE PEAKS

Bottom Construction

5429 Floors, which are generally to be spaced 610 mm (24 in) apart, are to have a depth and thickness not less than required by 5404 and their free edges are to be suitably stiffened.

Side Transverses

5430 Side transverses are to be spaced not more than 2,5 m (8·2 ft) apart and are to have a section modulus not less than:—

$$\frac{I}{y} = 9\, s_1\, h\, S^2\ \text{cm}^3 \qquad \left(\frac{I}{y} = \frac{s_1\, h\, S^2}{210}\ \text{in}^3\right)$$

In order to provide adequate end fixity for the side transverses, suitable transverses are to be arranged under the deck or flat in way of the side transverses, and the depth of floor in way is not to be less than that of the side transverse. The face bar of the transverse is to be continuous along the upper edge of the floor.

5431 If perforated flats are fitted to support the side transverses their scantlings are to be in accordance with 5439(1).

Side Longitudinals

5432 Fore peak side longitudinals are to have a section modulus not less than that required by 5425.

'TWEEN DECKS ABOVE FORE PEAKS

Side Transverses

5433 Side transverses in 'tween decks above fore peaks are to be in line with the peak side transverses and are to have a section modulus not less than required by 5427.

Side Longitudinals

5434 The section modulus of side longitudinals is to be in accordance with 5425.

Forecastles

5435 Web frames supporting side longitudinals are to have a section modulus not less than:—

$$\frac{I}{y} = 2{,}1\, C\, s_1\, h\, d\, \sqrt{D}\ \text{cm}^3$$

$$\left(\frac{I}{y} = \frac{C\, s_1\, h\, d \sqrt{D}}{500}\ \text{in}^3\right)$$

but h is not to be taken as less than the distance from the mid-point of span to the forecastle deck at side.

Their depth is not to be less than twice that of the longitudinals.

5436 Side longitudinals in the forecastle are to have a section modulus not less than:—

$$\frac{I}{y} = \frac{s\, S^2}{132}\left(0{,}6 + \frac{D}{6}\right)\ \text{cm}^3$$

$$\left(\frac{I}{y} = \frac{s\, S^2}{3000}\left(2 + \frac{D}{6}\right)\ \text{in}^3\right)$$

5437 Pillars supporting the forecastle deck are, in general, to be spaced not more than 3,7 m (12·1 ft) apart in the region forward of 0,04L abaft the forward perpendicular.

GENERAL

5438 The required section modulus of members attached to the shell is to be obtained about an axis parallel to the attached plating.

Deep Tanks Extending to Uppermost Continuous Deck

5439 Where in ships exceeding 180 m (590 ft) in length, the deep tanks extend to the uppermost continuous deck and a centreline bulkhead only is fitted, the web frames and side transverses, which are to be in accordance with 5407 and 5424 respectively, are to be supported by one of the following methods:—

(1) One or more perforated flats having a thickness not less than 9 mm (0·35 in) and an area of perforations not less than 10 per cent of the total area of the flat. The section modulus of the girders and beams or longitudinals on the flats may be 50 per cent of that required for an intact flat in the same position. Suitable transverses are to be arranged under the flats in way of the side transverses,

(2) One or more heavy side stringers having a section modulus not less than:—

$$\frac{I}{y} = 12{,}6\, b\, h\, S^2\ \text{cm}^3$$

$$\left(\frac{I}{y} = \frac{b\, h\, S^2}{150}\ \text{in}^3\right)$$

where b = breadth supported by the stringer, in metres (feet),

but h is not to be taken as less than the distance from the mid-point of span to the highest point of the tank, excluding the hatchway.

The ends of the stringers are to be connected to suitable stringers on the transverse bulkheads.

(3) Cross ties having scantlings required by D 4901 and having a vertical strut fitted at about mid-length. The dimensions of the strut are to be not less than those of the uppermost cross tie and it is to be effectively connected to the deck and bottom transverse and cross ties.

(4) Cross ties having scantlings required by D 4901 and having one or more fore and aft horizontal struts arranged to brace the cross ties between the deep tank bulkheads. The struts are to have a size appropriate to the cross ties supported.

5440 Where the longitudinal bulkheads are carried forward in deep tanks extending to the upper deck, the scantlings are to be as required by D46, D48 and D49.

Bulbous Bows

5441 The constructional arrangements required are dependent upon the shape and size of the bulb but, in general, the arrangement is to incorporate the following items:—

(i) Large bulbous bows are to have a centreline wash bulkhead and horizontal diaphragm plates spaced not more than 1 m (3·28 ft) apart at the fore end of the bulb.

(ii) Small bulbous bows need not have a centreline wash bulkhead but are to have horizontal diaphragm plates spaced not more than 1 m (3·28 ft) apart; normally these are to be in conjunction with a centreline web.

Where the length or width of a fore peak is unusually great due to fitting a bulbous bow, additional strengthening in the form of a transverse wash bulkhead at the mid-length of the peak-bulb space, may be required.

The shell plating in way of the bulb is, in general, to have a thickness required by D 1205. This increased plating should be extended to cover the areas likely to be damaged by the anchor and chain cables.

Continuity of Strength

5442 Continuity of strength is to be maintained at the scarphing of longitudinal and transverse framing and in cofferdams.

Construction of Bulkheads

5443 The scantlings of deep tank and peak tank bulkheads are to be in accordance with D 19, as applicable. For cofferdam bulkheads, *see also* D 5309.

Construction of Deep Tank Top

5444 The scantlings and arrangements of the deep tank top are to be as required by D 1919 and D 1920.

Cross-reference

5445 For structural details, *see* D 57.

Section 55

STRUCTURAL ARRANGEMENTS AT THE AFTER END

5501 Symbols:

L = length of ship, in metres (feet).

B = moulded breadth of ship, in metres (feet).

D = moulded depth, in metres (feet), to deck at side amidships.

D_1 = moulded depth, in metres (feet), but not to be taken as greater than 20 m (65·6 ft).

d = moulded draught, in metres (feet).

s = frame or longitudinal spacing, in mm (inches).

s_1 = spacing of web frames or stringers, in metres (feet).

S = span, in metres (feet).

h = distance, in metres (feet), from mid-point of span to upper deck at side amidships, unless stated otherwise.

C = a constant obtained from Fig. D 55.1.

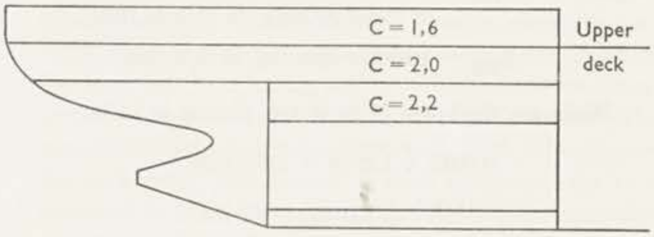


FIG. D 55.1

Construction

5502 Aft of the forward machinery space bulkhead the requirements contained in the following sections are applicable to transverse or longitudinal systems of framing as appropriate. If a combination of these arrangements is adopted equivalent strength is to be provided.

Double Bottom

5503 The double bottom is to be transversely framed. The scantlings and arrangements of the double bottom in way of the main propulsion machinery are to be suitable for its type and power. Sufficient fore and aft girders should be arranged to effectively distribute the weight of the machinery and ensure adequate rigidity, and they are to

extend aft under the thrust block seat. The tank top in way of the engine foundation should be substantially increased in thickness. The main engine seating should, in general, be integral with the double bottom structure; this particularly applies to higher power diesel and turbine installations. The general scantlings of the double bottom clear of the main machinery are to be not less than as follows:—

Minimum depth of centre girder D_{DB} =

$$\frac{1000B}{36} + 205\sqrt{d}\text{ mm} \qquad \left(\frac{B}{3} + 4{\cdot}5\sqrt{d}\text{ in}\right).$$

Thickness of centre girder =

$$0{,}008D_{DB}+4\text{ mm} \qquad (0{\cdot}008D_{DB}+0{\cdot}15\text{ in})$$

but may be 10 per cent less at aft end where clear of main engine seating.

Thickness of non-watertight floors and side girders =

$$0{,}008D_{DB}+1\text{ mm} \qquad (0{\cdot}008D_{DB}+0{\cdot}04\text{ in}).$$

Thickness of watertight floors = non-watertight thickness + 2 mm (0·08 in) but need not exceed 15 mm (0·59 in).

$\frac{I}{y}$ of watertight floor stiffeners =

$$\frac{D^2_{DB}\,h_{DB}\,s_{DB}}{185\times10^6}\text{ cm}^3 \qquad \left(\frac{D^2_{DB}\,h_{DB}\,s_{DB}}{600\,000}\text{ in}^3\right)$$

where D_{DB} = depth of double bottom, in mm (in),
h_{DB} = head from top of inner bottom to top of overflow pipe, in metres (feet),
s_{DB} = stiffener spacing, in mm (in).

Minimum thickness of tank top plating is to be:—

$$0{,}0015\sqrt[4]{Ld}\,(s + 660)\text{ mm}$$

$$(0{\cdot}00085\sqrt[4]{Ld}\,(s + 26)\text{ in}).$$

TRANSVERSE FRAMING SYSTEM

Framing

5504 Main frames in the engine room are to have a section modulus in accordance with D 707(1).

5505 'Tween deck and poop side frames are to have a section modulus in accordance with D 707(1). Where horizontal stringers having scantlings required by 5508 are fitted, they may be considered to be decks for the purpose of calculating the required frame section modulus.

5506 Aft of the line of the after peak bulkhead, peak and 'tween deck frames are to be spaced as required by D 706. Peak frames are to have a section modulus in accordance with D 713 and 'tween deck and poop frames aft of the line of the after peak bulkhead are to have a section modulus in accordance with D 707(3).

Web Frame and Side Stringers

5507 Web frames are to be fitted in the machinery space below the lowest deck or flat, not more than five frame spaces apart.

5508 Where a horizontal stringer giving full support to the side framing is fitted below the lowest deck or flat, the web frame section modulus is to be based on a stress of 9,5 kg/mm² (6 ton/in²), assuming fixed ends and point loading from the stringer, taking the head to upper deck at side amidships.

The section modulus of the stringer is not to be less than:—

$$7{,}75\,s_1\,h\,S^2\text{ cm}^3 \qquad \left(\frac{s_1\,h\,S^2}{245}\text{ in}^3\right)$$

5509 Where a horizontal stringer giving partial support to the side framing is fitted below the lowest deck or flat, the web frames are to have a section modulus not less than:—

$$7{,}75\,s_1\,h\,S^2\text{ cm}^3 \qquad \left(\frac{s_1\,h\,S^2}{245}\text{ in}^3\right)$$

The section modulus of the stringer is not to be less than:—

$$3{,}8\,s_1\,h\,S^2\text{ cm}^3 \qquad \left(\frac{s_1\,h\,S^2}{500}\text{ in}^3\right)$$

5510 Where no stringer is fitted the section modulus of the web frames is not to be less than:—

$$5{,}0\,s_1\,h\,S^2\text{ cm}^3 \qquad \left(\frac{s_1\,h\,S^2}{380}\text{ in}^3\right)$$

5511 The minimum depth of web frames in 5508, 5509 and 5510 is not to be less than 2,5 times the depth of the adjacent side frames.

The thicknesses of web frames and horizontal stringer webs are to be the same.

5512 Above the lowest deck, or equivalent, webs are to be fitted in line with the web frames below the deck and are to extend to the uppermost continuous deck. The section modulus of these web frames is not to be less than:—

$$1{,}67\,C\,s_1\,S\,d\sqrt{D}\text{ cm}^3 \qquad \left(\frac{C\,s_1\,S\,d\sqrt{D}}{625}\text{ in}^3\right)$$

Where there is no midship erection and all accommodation is fitted aft, sufficient web frames or partial bulkheads are to be fitted in the poop and in the superstructure above to ensure adequate transverse rigidity.

These webs should, in general, be in line with the web frames below the upper deck.

LONGITUDINAL FRAMING SYSTEM

Longitudinal Framing in Machinery Space

5513 In the machinery space the section modulus of the side longitudinals is not to be less than:—

$$\frac{I}{y} = \frac{s\,S^2}{153{,}5}\left(h + \frac{D_1}{6}\right)\text{cm}^3 \quad \left(\frac{I}{y} = \frac{s\,S^2}{3500}\left(h + \frac{D_1}{6}\right)\text{in}^3\right)$$

where h is not to be less than 0,9 m (3 ft).

Web Frames

5514 The section modulus of transverse webs in machinery spaces situated below the lowest deck or equivalent flat and supporting side longitudinals is not to be less than:—

$$\frac{I}{y} = 10\,s_1\,h\,S^2\,\text{cm}^3 \qquad \left(\frac{I}{y} = \frac{s_1\,h\,S^2}{190}\text{in}^3\right)$$

The spacing of web frames is not to be more than required by 5507.

5515 Above the lowest deck or equivalent, webs are to be fitted in line with the web frames below the deck and are to extend to the uppermost continuous deck. The section modulus of the web frames is not to be less than:—

$$\frac{I}{y} = 2{,}1\,C\,s_1\,S\,d\,\sqrt{D}\,\text{cm}^3$$

$$\left(\frac{I}{y} = \frac{C\,s_1\,S\,d\,\sqrt{D}}{500}\,\text{in}^3\right)$$

5516 When longitudinal framing is adopted above the after peak, transverse webs are to be fitted in the 'tween decks not more than four frame spaces apart. The section modulus of these webs is not to be less than:—

$$\frac{I}{y} = 2{,}1\,C\,s_1\,S\,d\,\sqrt{D}\,\text{cm}^3$$

$$\left(\frac{I}{y} = \frac{C\,s_1\,S\,d\sqrt{D}}{500}\,\text{in}^3\right)$$

5517 The section modulus of side longitudinals above the after peak and abaft the after peak bulkhead is not to be less than:—

$$\frac{I}{y} = \frac{s\,S^2}{117{,}5}\left(h + \frac{D_1}{6}\right)\text{cm}^3$$

$$\left(\frac{I}{y} = \frac{s\,S^2}{2680}\left(h + \frac{D_1}{6}\right)\text{in}^3\right)$$

where h is not to be less than 3 m (9·84 ft). Where, due to the shape of the vessel, the spacing of longitudinal exceeds 915 mm (36 in), intermediate longitudinals are to be fitted.

Poop Side Longitudinals

5518 Poop side longitudinals are to have a section modulus not less than:—

$$\frac{I}{y} = \frac{s\,S^2}{153{,}5}\left(0{,}6 + \frac{D_1}{6}\right)\text{cm}^3$$

$$\left(\frac{I}{y} = \frac{s\,S^2}{3500}\left(2 + \frac{D_1}{6}\right)\text{in}^3\right)$$

GENERAL

After Peak

5519 Floors in the after peak and counter are to have a thickness not less than that required by 5503. They are to be stiffened by flat bars or rolled sections of adequate size and spacing, bearing in mind possible vibratory forces which may arise in this region from the propeller. A centreline wash bulkhead having the same thickness as the floors is to be arranged in the after peak tank and counter. When transverse framing in accordance with 5505 is fitted above the after peak, web frames or their equivalent are to be arranged in the 'tween decks at every fourth frame abaft the after peak bulkhead.

5520 Frames, floors, stringers, girders, stiffeners and wash bulkheads in the after peak, or on the after peak bulkhead are not to be scalloped and the connection to shell or bulkhead is to be by double continuous welds.

Decks

5521 Lower decks or flats are to have sufficient strength and adequate end fixity when they are intended to support webs and side frames.

Strong Beams and Pillars

5522 Strong beams or other efficient cross ties are, in general, to be fitted in way of large machinery openings and are to be associated with suitable web frames. An efficient

pillaring system is to be provided under the engine casing and the casing sides are to be suitably stiffened in way of pillars. When the casing is used as a supporting girder suitable compensation is to be provided for openings.

Oil Fuel Bunkers

5523 The structural arrangements in the cargo tanks are to be maintained in oil fuel bunkers at the fore end of the machinery space. The scantlings are to be as required for cargo tanks, but the scantlings of cofferdam bulkheads where they are not cargo tank bulkheads are to comply with the requirements of D 5309 for plating and may have stiffeners as required by D 19.

Continuity of Strength

5524 Continuity of strength is to be maintained at the scarphing of longitudinal and transverse framing and in cofferdams.

The longitudinal deck framing is to extend one-third of the breadth of the ship into the poop. The side longitudinals are to extend abaft the poop front and the terminating positions of the longitudinal systems at sides and bottoms are to be staggered.

The longitudinal bulkheads are to extend well aft into the engine room and are to be suitably tapered at their ends.

Connections

5525 Web frames are to be suitably connected at top and bottom to members of adequate stiffness. Stringers are to be bracketed to the bulkheads. The stringer web and face plate are to be efficiently connected to the web frames.

Cross References

5526 For structural details and connections, *see* D 57. For section moduli of webs, girders, frames, etc., in association with plating, *see* D 53.

Section 56

SUPERSTRUCTURES AND DECKHOUSES

Forecastles

5601 All tankers are to be fitted with forecastles or increased sheer in accordance with the requirements of D 1702.

Superstructure Scantlings

5602 The scantlings of superstructures are to be as required by D 17, except that the upper limit of E_1 in D 1701, is to be 6,06 (1·20 British) instead of 5,55 (1·10 British). *See also* D 4203 and D 4204.

Deckhouse Scantlings

5603 The scantlings of deckhouses other than exposed casings and houses protecting openings to pump rooms are to be as required by D 17.

Houses Protecting Openings to Pump Rooms

5604 Houses protecting openings to pump rooms are to have end and side plating and end stiffeners as required for superstructures, irrespective of house size. The remaining items are to be as required for deckhouses.

Exposed Machinery Casings

5605 Exposed machinery casings, including the case where one end, or side, of a machinery casing forms part of an end or side of a superstructure or deckhouse, are to have scantlings as required by D 1706 and D 1707.

5606 There is not to be direct access to the machinery space from the freeboard deck.

Doors may be fitted in exposed machinery casings provided they lead to a space or passageway which is of equivalent strength to the casing, and is separated from the machinery space by a second weathertight door, *see* 5608.

Doors and Entrances

5607 Openings in poop fronts are to have sills not less than 450 mm (17·5 in) high.

5608 Doors in houses over pump rooms and in exposed machinery casings are to be of steel and weathertight. They are to be permanently attached by means of hinges and capable of being operated from both sides.

The door sills are to be not less than 600 mm (23·5 in) high if situated on the freeboard deck level, and not less than 380 mm (15 in) elsewhere.

General

5609 Where superstructures or deckhouses are of unusual design, additional strength may be required.

Section 57

STRUCTURAL DETAILS

Transverses, Webs, Stringers and Girders

5701 All primary supporting members, such as transverses and webs, stringers and girders, are to be so arranged that effective continuity of strength throughout their length is ensured and abrupt changes in depth or section at their connections are avoided; if the edges are flanged, the arrangement at the junction of the member and the bracket

is to be of careful design and execution. Primary supporting members are to have adequate end fixity, web stiffening and lateral support.

All longitudinals, stiffeners, etc., are to be attached to the primary supporting member as required by Table D 57.6.

Arrangements at Ends of Primary Supporting Members

5702 When face plates are carried continuously along the edges of end brackets of primary supporting members, their butts are to be kept clear of the toes of the brackets. The full width of the face plate is to be determined as far as the span point.

If not carried along the edge of the bracket the face plates of these members are to extend a reasonable distance beyond the toes of the brackets.

Where a wide face plate abuts on a narrower face plate, the taper is generally not to exceed 1 in 3, elsewhere the taper may be 1 in 2. Where a thick face plate abuts on a thinner face plate, if the difference in thickness exceeds 3 mm (0·125 in), the taper on the thickness is not to exceed 1 in 3.

5703 End brackets are to be stiffened as in Table D 57.1.

The bracket stiffener, when required, is to be parallel to the free edge and generally not more than a quarter of the throat depth from it. Large brackets may also require stiffening in line with the girder face plate.

The thickness of the end bracket is not to be less than the thicker of the webs being connected unless additional stiffeners are fitted when the thickness may be reduced by 1 mm (0·04 in), provided the compartment minimum is maintained.

TABLE D 57.1

Length of free edge		Bracket stiffening	
Above	Not exceeding	Flange or face plate	Additional flat stiffener
mm (in)	mm (in)	mm (in)	mm (in)
—	1270 (50)	100 (4)	—
1270 (50)	1650 (65)	125 (5)	—
1650 (65)	2030 (80)	125 (5)	100 (4)
2030 (80)	2540 (100)	150 (6)	100 (4)
2540 (100)	—	200 (8)	125 (5)

5704 Brackets are to be well hollowed out or attached to a flat on the bulkhead plating. The flat is to extend to an adjacent stiffener or is to be well tapered off.

End brackets to horizontal girders on the transverse bulkheads are to be carried to the adjacent transverse and vertical web or equivalent arrangements provided.

5705 The angle between the free edge of the bracket and the face plate of the primary member is not to exceed 45°; if necessary, the edge of the bracket is to be curved at the toe.

5706 Special attention is to be paid to the tripping brackets of girders or webs on corrugated bulkheads to avoid causing hard spots on the bulkhead. All brackets are to be well hollowed and are to be situated as close to the corner of the corrugation as practicable, or other suitable arrangements made to dissipate the load at the bracket toe.

5707 Where members abut on both sides of bulkheads or on other members care is to be taken that they are in alignment.

Web Stiffening

5708 Stiffeners are to be fitted to web plates at each frame, longitudinal or bulkhead stiffener except that on deck transverses and on side transverses and vertical webs within 0,25D from the deck at side, the stiffeners need only be fitted at alternate longitudinals. Elsewhere the spacing of stiffeners is generally not to be more than 1050 mm (42 in).

Flat bar stiffeners are to have the depth given in Table D 57.2 and minimum compartment thickness. Other types of stiffeners are to be of equivalent inertia.

Where the depth of the web exceeds 1525 mm (60 in) the stiffening arrangements will be specially considered, taking into account the number of attached girders, etc., and any stiffeners arranged parallel to the face plate of the girder.

Long stiffeners are to extend to the face edge of the web. In way of end brackets, or where required by 5713, the stiffeners are to be attached to the face plate or equivalent arrangements provided.

Short stiffeners are to extend to half the depth of the web but at least beyond the lightening holes or 150 mm (6 in) beyond the notches.

The requirements of Table D 57.6 as regards area of weld are also to be complied with.

5709 Where bulkheads are horizontally corrugated and the vertical webs are arranged on one side of the bulkhead only, vertical stiffening of the web is to be provided when the depth of the web exceeds 1065 mm (42 in). The stiffener should be a 150×90 mm (6×3·5 in) toe welded angle of minimum compartment thickness or equivalent area.

TABLE D 57.2

Depth of Girder		Stiffeners	
Above	Not exceeding		
mm (in)	mm (in)	mm (in)	
—	610 (24)	75 (3)	Short and long alternately*
610 (24)	915 (36)	100 (4)	Short and long alternately*
915 (36)	1065 (42)	125 (5)	Short and long alternately*
1065 (42)	1220 (48)	125 (5)	All long
1220 (48)	1525 (60)	150 (6)	All long

* All long in way of end brackets.

5710 Vertical webs on plane transverse bulkheads are to be stiffened in accordance with 5709 when the depth of web exceeds 1900 mm (76 in). Similar stiffening may be required on other vertical webs when the depth is excessive.

5711 Stiffeners of the size given in 5708 are generally to be fitted to the deck centreline girder and bottom and deck side girders not more than 1050 mm (42 in) apart. All stiffeners are to extend to the face plate. In deep centre line girders horizontal stiffening is to be arranged.

Lateral Stability

5712 Tripping brackets are to be fitted at suitable intervals. In general, they should be fitted near the toes of end brackets and in way of cross ties, while arrangements at the intersections of longitudinal and transverse webs, vertical and horizontal webs should be adequate to prevent tripping. Where the span is long, additional brackets are to be fitted as necessary.

5713 Where the unsupported width of face plate exceeds 150 mm (6 in) the tripping bracket is to be connected to the face plate. Where, with symmetrically placed face plates, the width of face plate exceeds 400 mm (16 in) a small bracket connected to the face plate is to be fitted opposite, and in line with, the tripping bracket. Wide face plates may require to be supported between tripping brackets.

Notches

5714 All notches are to have well rounded corners and smooth edges and are not to be larger than necessary. When notches occur at points where stress concentration may develop, such as adjacent to the toes of brackets, a welded collar or equivalent reinforcement is to be fitted. Collars are also to be fitted in way of cross ties.

Lightening, Access, Drain and Air Holes and Holes for Heating Coils, etc.

5715 The diameter of lightening holes is not to exceed 20 per cent of the depth of the web; the edges of the holes should be placed at not less than 40 per cent of the depth of the web from the face and equidistant from the corners of notches for frames or stiffeners. Lightening holes are not to be cut in horizontal girders on the ship's side and longitudinal bulkheads, in symmetrical webs nor in side transverses and vertical webs in way of cross ties and their end connections. Access holes or foot holes may be cut in deep bottom transverses and centre girders with suitable compensation if necessary. All holes are to have smooth edges and are to be kept well clear of notches and the toes of brackets.

5716 Small drain or air holes may be cut in deep framing members and in longitudinals and stiffeners. These holes should be kept clear of the toes of end brackets and are to be well rounded with smooth edges. (*See also* D 4102 and Table D 41.2 Note 4).

5717 Where holes are cut in the bottom transverses for heating coils the lower edge of the hole is to be not less than 100 mm (4 in) from the inside of the shell plating.

5718 The edges of all holes in transverses are to be at least 180 mm (7 in) from the edges of notches for longitudinals.

Welded Connections

5719 The requirements for welded connections and details of scalloped construction are given in Tables D 57.3, D 57.4, D 57.5 and D 57.6. All scallops are to have well rounded corners and smooth edges. (For general particulars *see* Table D 57.3.) Scallops are not to be cut in way of end brackets, and scallops in the stiffening members are to be at least 230 mm (9 in) clear of the toe of the bracket. Scallops in longitudinals, side frames and stiffeners are also to be omitted for at least 230 mm (9 in) on each side of intersection with a primary supporting member. Scallops are nct to be cut in bottom transverses or in horizontal girders on ship's side or longitudinal bulkheads, and in ships over 122 m (400 ft) in length, scallops are not to be cut in the lower half of side transverses or vertical webs on longitudinal and transverse bulkheads.

TABLE D 57.3 *(see continuation)*

WELDING OF VARIOUS STRUCTURAL CONNECTIONS

ITEM			WELD FACTOR
FRAMES & LONGITUDINALS			
Side frames to shell	in cargo tanks, spacing not over 760 mm (30 in) ...		0,11 (0·16)
	in cargo tanks, spacing over 760 mm (30 in)		0,12 (0·17)
	in deep, oil fuel and peak tanks		0,12 (0·17)
	in fore hold		0,12 (0·17)
	in machinery space, spacing not over 740 mm (29 in) ...		0,09 (0·13)
	in machinery space, spacing over 740 mm (29 in) and up to 810 mm (32 in)		0,10 (0·14)
	in machinery space, spacing over 810 mm (32 in) and up to 860 mm (34 in)		0,11 (0·16)
	in machinery space, spacing over 860 mm (34 in) ...		0,12 (0·17)
Tween deck frames and longitudinals to shell			0,09 (0·13)
Web frames			*See* Table D 57.4
Bottom longitudinals to shell (except as below)	for a distance either side of the bulkhead equal to 0,30× spacing of transverses		0,35 (0·50) 0,11 (0·16) when longitudinals continuous at bulkhead
	remainder (except in the forward 0,25 L)		0,11 (0·16)
	in the forward 0,25 L (except at ends of span, where as above)		0,22 (0·32)
Bottom longitudinals of flatbar type to shell			Continuous weld 0,25 (0·35) but need not exceed 5,5 mm (0·30 in) hand or 4,5 mm (0·25 in) automatic (*see also* Note 1—Table D 57.3)
Side longitudinals to shell	not over 4,6 m (15 ft) below upper deck at side amidships		0,11 (0·16)
	over 4,6 m (15 ft) and not over 7,6 m (25 ft) below upper deck at side amidships	for a distance either side of bulkhead equal to 0,25 × spacing of transverses	0,35* (0·50)* 0,11 (0·16) when longitudinals continuous at bulkhead
		remainder	0,11 (0·16)
	over 7,6 m (25 ft) below upper deck at side amidships	for a distance either side of bulkhead equal to 0,25 × spacing of transverses	0,35 (0·50)
		remainder	0,11 (0·16)
Deck longitudinals to deck plating, except as below			0,11 (0·16)

* May be 0,28 (0·40) clear of oil cargo tanks

TABLE D 57.3 (*see continuation*)

WELDING OF VARIOUS STRUCTURAL CONNECTIONS

ITEM	WELD FACTOR
Deck longitudinals of flatbar type to deck plating	Continuous weld—0,25 (0·35) but need not exceed 5,5 mm (0·30 in) hand or 4,5 mm (0·25 in) automatic (*see also* Note 1)
Longitudinals to stiffening bars on primary supporting members	*See* Table D 57.6
Intercostal bottom side girders to shell	As for bottom longitudinals
Intercostal deck side girders to deck plating	As for deck longitudinals
Face bar of intercostal bottom and deck side girders to respective web plates	0,13 (0·19)
Bottom frames to shell and floors forward	0,22 (0·32)
Floors to centre girder or centre line bulkhead forward	0,44 (0·63)
Floors and cross ties in fore peak	0,11 (0·16)
Floors and cross ties in after peak	0,13 (0·19)
PRIMARY SUPPORTING MEMBERS	
Bottom transverses to shell	*See* Table D 57.4
Side transverses to shell...	*See* Table D 57.4
Deck transverses to deck plating	*See* Table D 57.4
Web frames to shell	*See* Table D 57.4
Vertical webs on longitudinal and transverse bulkheads	*See* Table D 57.4
Stringers to shell	*See* Table D 57.4
Horizontal girders to O.T. bulkheads	*See* Table D 57.4
Bottom transverses to longitudinal bulkheads and centre line girder ...	0,44 (0·63)
Deck transverses to longitudinal bulkheads and centre line girder ...	0,35 (0·50)
BRACKETS	
End brackets of all primary supporting members	0,44 (0·63)
Brackets at head of side frames	*See* Table D 57.5
Side frames to bilge brackets	To depend on arrangements adopted
End connections of longitudinals	Generally 0,44 (0·63) but to depend on design
Brackets at ends of stiffeners on transverse bulkheads	To depend on end connections of longitudinals
Tripping brackets	0,11 (0·16)
Docking brackets	0,13 (0·19)
Stiffening of primary supporting members. *See also* Table D 57.6 ...	0,09 (0·13)

TABLE D 57.3 (*concluded*)

WELDING OF VARIOUS STRUCTURAL CONNECTIONS

ITEM				WELD FACTOR
O.T. TRANSVERSE & LONGITUDINAL BULKHEADS				
Vertical stiffeners	spacing not exceeding 760 mm (30 in)			0,11 (0·16)
	spacing exceeding 760 mm (30 in)			0,12 (0·17)
Horizontal stiffeners	not over 4,6 m (15 ft) below highest point of tank ...			0,11 (0·16)
	on longitudinal bulkheads	over 4,6 m (15 ft) and not over 7,6 m (25 ft)	for a distance either side of bulkhead equal to 0,25×spacing of transverses	0,35 (0·50) 0,11 (0·16) when longitudinals continuous at bulkhead
			remainder	0,11 (0·16)
		over 7,6 m (25 ft)	for a distance either side of bulkhead equal to 0,25×spacing of transverses	0,35 (0·50) 0,11 (0·16) when longitudinals continuous at bulkhead
			remainder	0,11 (0·16)
	on transverse bulkheads	not over 5,5 m (18 ft) below highest point of tank		0,11 (0·16)
		over 5,5 m (18 ft)		0,13 (0·19)
Boundaries	of longitudinal bulkheads to bottom or deck			0,44 (0·63) (continuous) *See* note 5
	of transverse bulkheads	to shell at bottom or bilge		0,44 (0·63) (continuous)
		to shell at sides or to deck		0,35 (0·50) (continuous)
		to longitudinal bulkheads		0,35 (0·50) (continuous)
Vertical webs ... ... Horizontal girders				*See* Table D 57.4

NOTES.—TABLE D 57.3

1. Thickness to be used in determining throat thickness (leg length) is generally to be that of the thinner of the two parts being joined.

Where slab type longitudinals are fitted to the bottom shell, upper deck, or longitudinal oiltight bulkheads in the upper or bottom 0,1D, within 0,4L amidships, the thickness used to determine the throat thickness (leg length) is not to be taken as less than half the thickness of the longitudinal.

Where the difference between the thicknesses of the parts to be joined is considerable the size of fillet will be specially considered.

2. Throat thickness (leg length) for double continuous fillets is to be the product of the plate thickness and the weld factor given in Table D 57.3.

Within the cargo tanks double continuous fillets having a throat thickness (leg length) of less than 0,35 (0·50) of the plate thickness are to be restricted to longitudinal framing and to bulkhead stiffening.

Where automatic deep penetration welds are used the values derived as above may be reduced by 15 per cent.

In no case (except for slab longitudinals) is the throat thickness (leg length) to be less than 0,21 × plate thickness (0·30 × plate thickness) nor is it to be less than 3,5 mm (0·18 in) for hand and automatic welding or 3 mm (0·16 in) for automatic deep penetration welding.

For hand welded fillet welds on internal bulkheads not exceeding 6 mm (0·24 in) in thickness a minimum throat thickness (leg length) of 3 mm (0·16 in) is acceptable.

3. Throat thickness (leg length) for intermittent fillets is to be given by the formula:—

Throat thickness (leg length) =

$$\text{plate thickness} \times \text{weld factor} \times \frac{d}{s}$$

where d and s are defined in Fig. 57.1.

The length s should not be less than 75 mm (3 in) and the ratio of s and d is to be such that the required throat thickness (leg length) does not exceed 0,49 × plate thickness (0·70 × plate thickness) or 4,5 mm (0,24 in) whichever be the greater.

In no case, however, is the throat thickness (leg length) of intermittent fillet welds to be less than 0,28 × plate thickness (0·40 × plate thickness) or 3,5 mm (0·18 in) whichever be the greater.

4. Leg length of welds is to be not less than 140 per cent of the throat thickness derived as above or as required by Table D 57.5, Note 2.

or in British units:—

4. Throat thickness of welds is to be not less than 70 per cent of the leg length derived as above or as required by Table D 57.5, Note 2.

5. Where the top and bottom strakes of the longitudinal bulkhead are increased in thickness above the requirements of D 5007, the welding to deck or bottom shell is not to be less than that based on the thickness required by D 5007 or a throat thickness (leg length) 25 (35) per cent of the actual plating thickness, whichever is the greater.

6. Fillet welds in after peak tanks or on after peak bulkhead stiffeners are to be continuous. It is recommended that all fillet welds in all tanks be continuous.

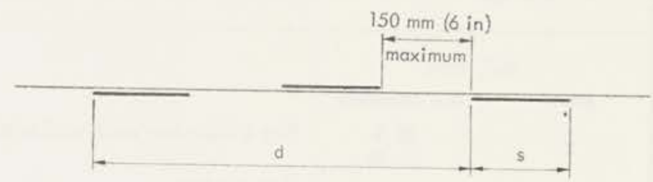
Where the thickness of bottom or deck longitudinals exceeds the thickness of the shell or deck plating the welding is to be continuous.

7. Welding at the ends of bulkhead stiffeners etc., (whether associated with brackets or lugs) is to give, when not otherwise specified in Tables D 57.3, D 57.4, D 57.5 and D 57.6, a weld area (length of weld × throat thickness) of 25 per cent of the cross sectional area of the stiffener with a minimum of 6,5 cm^2 (1 in^2).

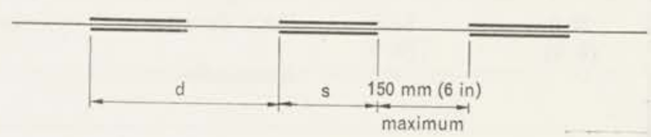
8. The welding of girders, webs, beams and frames to shell and deck in way of end brackets or knees that require continuous welds, should also be continuous.

STAGGERED INTERMITTENT

To be doubled at ends. *See* D 3210



CHAIN INTERMITTENT



SCALLOPED FRAMES, LONGITUDINALS, STIFFENERS, etc., WITH DOUBLE FILLET WELDS

Welding to be carried round the ends of all lugs
See also D 5719

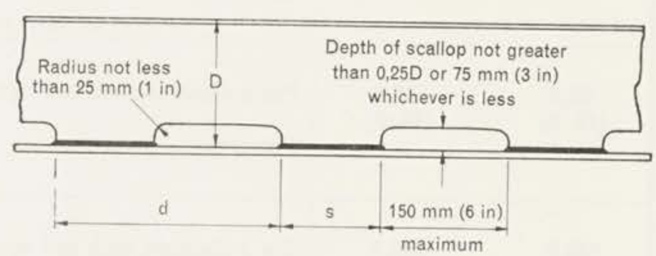


FIG. D 57.1 WELD TYPES

TABLE D 57.4

CONNECTION OF PRIMARY SUPPORTING MEMBERS TO FACE MATERIAL, SHELL, DECK AND BULKHEAD

FACE AREA		POSITION	WELDED	
			TO FACE MATERIAL	TO SHELL, DECK OR BULKHEAD
			WELD FACTOR	WELD FACTOR
cm^2 (in^2) Above	Not exceeding			
	30,0 (5·0)	For a distance each end equal to 0,2×length ...	0,15 (0·21)	0,30 (0·42)
		Remainder	0,10 (0·14)	0,15 (0·21)
30,0 (5·0)	65,0 (10·0)	For a distance each end equal to 0,2×length ...	0,22 (0·31)	0,35 (0·50)
		Remainder	0,12 (0·16)	0,27 (0·38)
65,0 (10·0)	95,0 (15·0)	For a distance each end equal to 0,2×length ...	0,35 (0·50)	0,44 (0·63)
		Remainder	0,35* (0·50)*	0,35 (0·50)
95,0 (15·0)	130,0 (20·0)	For a distance each end equal to 0,2×length ...	0,35 (0·50)	0,44 (0·63)
		Remainder	0,35* (0·50)*	0,35 (0·50)
130,0 (20·0)	260,0 (40·0)	For a distance each end equal to 0,2×length ...	0,44 (0·63)	0,44 (0·63)
		Remainder	0,35 (0·50)	0,35 (0·50)

* May be 0,28 (0·40) clear of oil cargo tanks

NOTES.—TABLE D 57.4

1. Length for use in the above Table is the unsupported length of the member including end connections.

2. The extent of the increased connection at each end equal to 0,2×length given in the above Table is measured from the end of the member including the end bracket, but this length is to be extended as necessary beyond the toe of the bracket, and beyond the heel of the bracket to cover a contiguous member.

3. On vertical webs the increased welding may be omitted at the top, but at the bottom it is to extend for a distance equal to 0,3×length.

4. In ships over 122 m (400 ft) long the weld factor of the connection of bottom transverses to the shell is not to be less than 0,35 (0·50) and that of the side transverses to shell, and the vertical webs to longitudinal and transverse bulkheads is not to be less than 0,35 (0·50) in the lower half.

5. Centre line deck and bottom girders are to be welded as given in the above Table.

6. For particulars of scalloped construction, *see* D 5719 and notes under Table D 57.3.

TABLE D 57.5

BRACKETS AT HEAD OF SIDE FRAMES AND AT ENDS OF VERTICAL STIFFENERS TO LONGITUDINAL AND TRANSVERSE BULKHEADS

1. The dimensions of brackets and their connections are not to be less than those given by the following formulæ:—

Length of Arm (l) $= 28{,}3\sqrt{\dfrac{I}{y}} + 50$ mm

(Length of Arm (l) $= 4{\cdot}5\sqrt{\dfrac{I}{y}} + 2$ in).

Thickness $= 0{,}184\sqrt{\dfrac{I}{y}} + 6{,}5$ mm, or 9 mm, whichever is the greater but need not exceed 12,5 mm

(Thickness $= 0{\cdot}03\sqrt{\dfrac{I}{y}} + 0{\cdot}25$ in, or 0·36 in, whichever is the greater but need not exceed 0·50 in).

Flange Width (*see* 4 below) $= 3{,}14\sqrt{\dfrac{I}{y}} + 12{,}5$ mm, or 100 mm, whichever is less

(Flange Width (*see* 4 below) $= 0{\cdot}5\sqrt{\dfrac{I}{y}} + 0{\cdot}50$ in, or 4 in, whichever is less).

Weld Area (*see* 2 below) $= 0{,}042\,l$ cm² if $l \leqslant 610$ mm

(Weld Area (*see* 2 below) $= \dfrac{l}{6}$ in² if $l \leqslant 24$ in).

Weld Area (*see* 2 below) $= 0{,}064\,l - 13$ cm² if $l > 610$ mm

(Weld Area (*see* 2 below) $= \dfrac{l}{4} - 2$ in² if $l > 24$ in).

Where $\dfrac{I}{y}$ = Section modulus of frame or stiffener in cm³ (in³).

2. Area of weld is the product of the throat thickness and the total length of weld, but the throat thickness is not to be less than 0,35 of the plate thickness, or 3 mm (0·12 in), whichever be the greater. (*See* Table D 57.3).

3. Length of bracket arm is to be measured from the plating.

4. Flanges need not be fitted where the length of bracket arm is less than 460 mm (18 in).

5. For minimum thickness, *see* D 5309.

TABLE D 57.6

CONNECTIONS OF LONGITUDINALS, FRAMES AND STIFFENERS TO PRIMARY SUPPORTING MEMBERS

1. The weld area connecting longitudinals, frames and stiffeners to primary supporting members is not to be less than the greater of the values given by the following formulæ:—

Bottom Transverses $A = 0{,}88 \sqrt{\frac{I}{y}}$ or $0{,}0612 \frac{1}{S} \frac{I}{y}$ cm²

$\left(A = 0{\cdot}55 \sqrt{\frac{I}{y}}\right.$ or $\left.0{\cdot}51 \frac{1}{S} \frac{I}{y} \text{ in}^2\right)$

Deck Transverses $A = 0{,}44 \sqrt{\frac{I}{y}}$ or $0{,}0306 \frac{1}{S} \frac{I}{y}$ cm²

$\left(A = 0{\cdot}275 \sqrt{\frac{I}{y}}\right.$ or $\left.0{\cdot}255 \frac{1}{S} \frac{I}{y} \text{ in}^2\right)$

Side Transverses and bulkhead webs and girders $A = 0{,}88 \sqrt{\frac{I}{y}}$ or $0{,}109 \frac{1}{S} \frac{I}{y}$ cm²

$\left(A = 0{\cdot}55 \sqrt{\frac{I}{y}}\right.$ or $\left.0{\cdot}908 \frac{1}{S} \frac{I}{y} \text{ in}^2\right)$

In no case is the area to be less than 13 cm² (2 in²)

where A = area of weld in cm² (in²) as defined in 2 below.

$\frac{I}{y}$ = section modulus of longitudinal, frame or stiffener in cm³ (in³).

S = span of longitudinal, frame or stiffener in metres (feet).

2. Area of weld is the product of the throat thickness and total length of weld and includes both weld of web connection and weld of connection to stiffening bar. The throat thickness is not to be less than 0,35 of the plate thickness, or 3 mm (0·12 in) whichever be the greater (*see* Table D 57.3).

3. Outside the tank space the area of weld may be 80 per cent of the value required by the formula and associated notes. The throat thickness of weld is not to be less than 0,30 of the plate thickness or 3 mm (0·12 in) whichever be the greater.

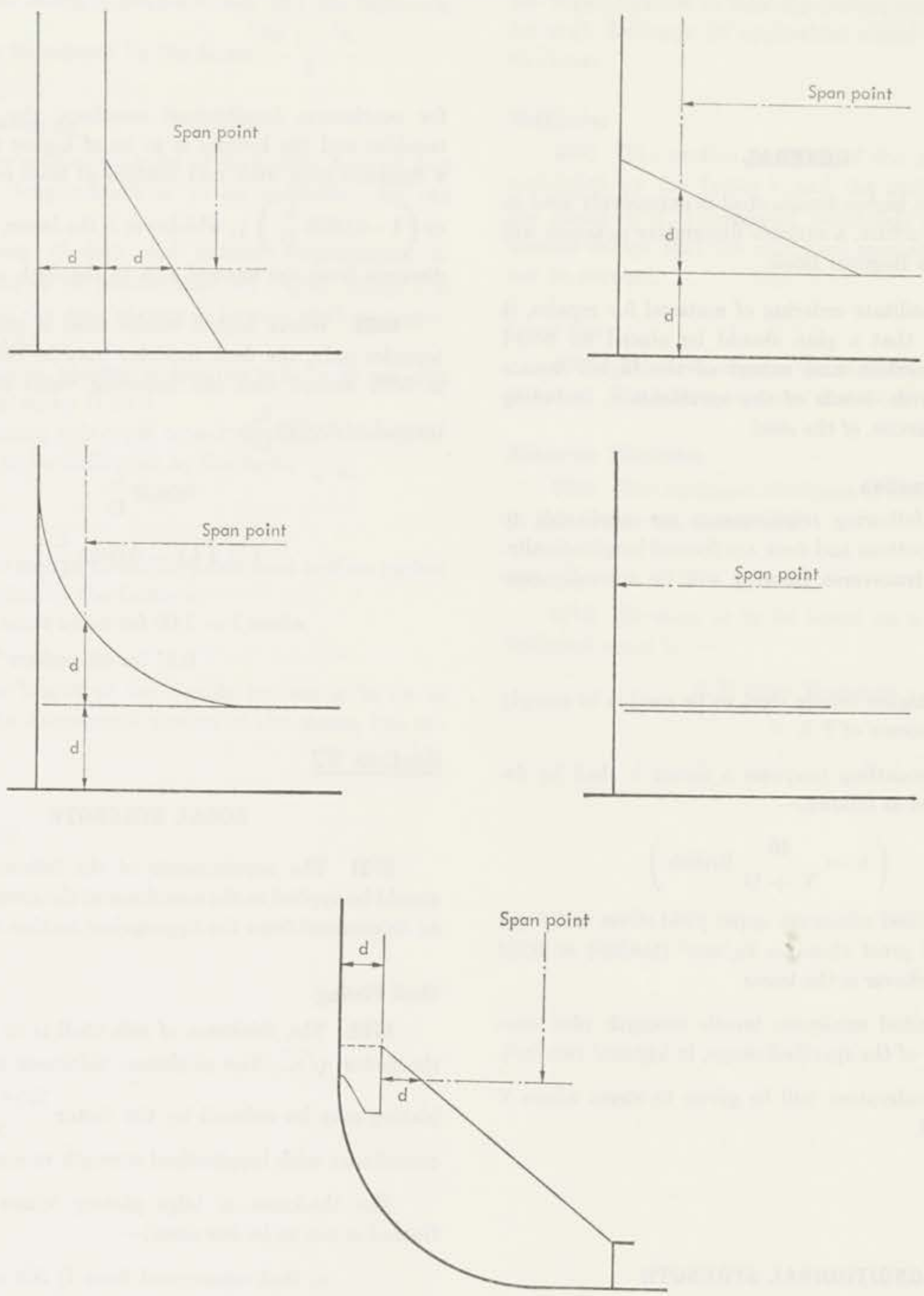


FIG. D 57.2 SPAN POINT FOR LONGITUDINALS, FRAMES AND STIFFENERS

APPLICATION OF HIGHER TENSILE STEEL

Section 65

GENERAL

6501 Where higher tensile steel is extensively used in the main hull structure, a suitable descriptive notation will be inserted in the Register Book.

6502 To facilitate ordering of material for repairs, it is recommended that a plan should be placed on board indicating the location and extent of the higher tensile steel, together with details of the specification, including mechanical properties, of the steel.

Method of Construction

6503 The following requirements are applicable to ships where the bottom and deck are framed longitudinally. Proposals with transverse framing will be specially considered.

Material

6504 The higher tensile steel to be used is to comply with the requirements of P 3.

6505 For scantling purposes a factor k shall be derived for the steel as follows:—

$$k = \frac{70{,}9}{Y + U} \qquad \left(k = \frac{45}{Y + U} \text{ British} \right)$$

where Y = specified minimum upper yield stress or 0,5 per cent proof stress in kg/mm² (ton/in²) or 0,7U whichever is the lesser.

U = specified minimum tensile strength plus one-half of the specified range, in kg/mm² (ton/in²).

Special consideration will be given to steels where Y is less than 0,5U.

Section 66

LONGITUDINAL STRENGTH

6601 The required section moduli at deck and keel, as determined from D 3 or D 41, are to be multiplied by the factor k or by $0{,}0625 \frac{L}{D}$, whichever is the greater. Where both higher tensile steel and ordinary mild steel are used for continuous longitudinal members, the whole of the topsides and the bottom is to be of higher tensile steel to a distance from deck and bottom at least equal to $(1-k)y$ or $\left(1-0{,}0625 \frac{L}{D}\right) y$, whichever is the lesser, where y is the distance from the neutral axis to the deck or bottom.

6602 Where higher tensile steel is proposed for the topsides only, the deck modulus may be reduced as given in 6601 except that the following value should be used instead of $0{,}0625 \frac{L}{D}$:—

$$\frac{0{,}0625 \frac{L}{D}}{1 + f\left(1 - 0{,}0625 \frac{L}{D}\right)}$$

where f = 1,00 for cargo ships
0,97 for oil tankers

Section 67

LOCAL STRENGTH

6701 The requirements of the following paragraphs should be applied to the scantlings of the structural members as determined from the appropriate section of the Rules.

Shell Plating

6702 The thickness of side shell is to be reduced by the factor $\sqrt{k}$. The minimum thickness of bottom shell plating may be reduced by the factor $\frac{2k+\sqrt{k}}{3}$ subject to compliance with longitudinal strength requirements.

The thickness of bilge plating where longitudinally framed is not to be less than:—

(a) that determined from D 504 or D 4304 with no correction for higher tensile steel,

(b) that determined from D 504 (a) or D 4302, using the actual spacing of bilge longitudinals and corrected as given above for bottom shell, whichever is the lesser.

Deck Plating

6703 The thickness of deck plating is to be determined by longitudinal strength requirements, and the minimum thickness may be reduced by the factor $\frac{2k+\sqrt{k}}{3}$

Longitudinal Framing

6704 The section modulus of deck, side, bottom and inner bottom longitudinals is to be multiplied by the factor k.

The spacing of deck and bottom longitudinals, in mm (in), is not to be greater than 65 $t\sqrt{k}$, where t is the thickness of the deck plating or bottom shell, as appropriate, in mm (in).

The minimum breadth of face bar is to be 15 per cent greater than given by D 4404.

The maximum web depth to web thickness ratios given in D 4404 are to be multiplied by the factor $\sqrt{k}$.

Girders

6705 The section modulus of deck and bottom girders is to be multiplied by the factor k.

Double Bottom

6706 The height of the double bottom is to be as required by the appropriate section of the Rules, but the thicknesses of floors, girders and tank top are to be multiplied by the factor $\sqrt{k}$. The factor should be applied to the Rule thickness of tank top plating and the full increase for grab discharge (if applicable) added to this corrected thickness.

Bulkheads

6707 The section modulus of the stiffeners is to be multiplied by the factor k and the plating thickness by the factor $\sqrt{k}$. Corrugated bulkheads may be similarly treated except that the minimum moment of inertia shall not be reduced.

Cross Ties

6708 The area of cross ties is to be multiplied by the factor k. The least moment of inertia shall not be reduced.

Minimum Thickness

6709 The minimum thickness of structural items is to be reduced by the factor $\sqrt{k}$.

Riveting

6710 Riveting is to be based on a nominal plating thickness equal to:—

$$\frac{\text{H.T. Steel Thickness}}{k}$$

23rd July, 1970

REQUIREMENTS FOR THE CARRIAGE OF LIQUEFIED GASES

(*The attention of Builders and Owners is directed to the fact that compliance with these Rules may involve the obtaining of licences under existing patents.*)

Section 70

GENERAL

Class

7001 The class 100A1 Liquefied Gas Carrier, type of gas(es) in independent tanks, maximum vapour pressure, minimum temperature and, where necessary, maximum temperature (to be specified), will be assigned to ships specially designed for the carriage of liquefied petroleum natural or other gases in separate tanks and built in accordance with, or equivalent to, the relevant sections of the Rules and the requirements in this section in conjunction with D 71 or D 72 as appropriate.

These requirements are primarily intended to apply to ships having machinery aft and built for the carriage of liquefied petroleum or natural gases in separate tanks and special consideration will be given to the requirements necessary for other liquefied gases. Arrangements incorporating integral or membrane tanks will also be specially considered.

Longitudinal Strength

7002 The required section modulus at deck and keel is to be determined in accordance with D 3 of the Rules as required therein for the class 100A1.

Extent of Midship Scantlings

7003 The midship scantlings are to be maintained from 0,2L aft of amidships to 0,2L forward of amidships.

Grades of Steel

7004 Where the thickness of plating exceeds 20,5 mm (0·80 in) and the seams and butts are welded, steel of Grade D (*see* Table P 2.2) will generally be required for the following parts of the structure:—

(*a*) Sheerstrake, strength deck stringer and plating, top strake of the longitudinal bulkhead (where fitted), deck longitudinals of the slab type where cut from plates and through brackets for deck longitudinals from 0,2L aft of amidships to 0,2L forward of amidships, but at least 3 m (10 ft) forward of the bridge front.

Sheerstrake and strength deck stringer and plating in way of poop front.

Any stringer or sheerstrake plating outside these limits which is above 25,5 mm (1 in) in thickness.

(*b*) Bottom shell plating to upper turn of bilge, bottom strake of longitudinal bulkhead (where fitted), bottom longitudinals of the slab type where cut from plates and through brackets of bottom longitudinals from 0,15L aft of amidships to 0,15L forward of amidships where the length is 153 m (503 ft) and below, and from 0,2L aft of amidships to 0,2L forward of amidships where the length is 215 m (705 ft) and above with intermediate values obtained by interpolation.

Where the bottom plating is required to be of steel of Grade D the keel is also to be of the same grade.

7005 Strakes of Grade E steel are to be arranged as required by D 513.

7006 For scantlings and arrangements if higher tensile steel is used, *see* D 65, D 66 and D 67.

Double Bottom Structure

7007 The scantlings of the double bottom structure are to be determined in accordance with D 9. Where wing ballast tanks or floodable cofferdams are common with the double bottom tanks, the scantlings of the tank top must also satisfy D 19.

Bottom Shell

7008 The thickness of the bottom shell amidships to upper turn of bilge is to be that necessary to give the required section modulus but is not to be less than required by D 5.

Side Shell

7009 The thickness of the side shell plating is to be determined from D 5.

Transverse Side Framing

7010 The scantlings of transverse side frames are to be obtained from D 7. Where an inner hull is provided and the side frames are supported by stringers the required section modulus of the frames is to be in accordance with the requirements of D 719 to D 722.

Longitudinal Side Framing

7011 The section modulus of side longitudinals is to be not less than:—

$$\frac{I}{y} = \frac{s\,S^2}{118}\left\{h + \frac{2{,}5d - D}{6}\right\}\text{cm}^3$$

$$\left(\frac{I}{y} = \frac{s\,S^2}{2680}\left\{h + \frac{2\cdot 5d - D}{6}\right\}\text{in}^3\right)$$

where s = spacing of longitudinals, in mm (in),

S = span, in metres (feet), measured between transverses or from transverse to "span point",

h = distance of longitudinal below deck at side, in metres (feet),

d = summer draught measured from top of keel, but not less than 0,4D, in metres (feet).

7012 Side transverses are to be spaced not more than 3,66 m (12 ft) apart and the section modulus is to be not less than:—

$$\frac{I}{y} = \frac{s\,h\,S^2}{k}\ \text{cm}^3\quad(\text{in}^3)$$

where s = spacing of transverses, in metres (feet),

S = span of transverses, in metres (feet),

h = head from midpoint of span to deck at side, in metres (feet),

k = $81{,}6\times10^{-3}$ (155 British) when d/D = 0,75 and above,

$94{,}8\times10^{-3}$ (180 British) when d/D = 0,50 or below,

with intermediate values by interpolation.

The requirements of D 4608 and D 4609 are to be complied with.

Inner Hull

7013 Where an inner hull is fitted to form wing ballast tanks (*see* D 7102) the scantlings are to be as required by D 19.

7014 The width of the wing tank and the spacing of the side transverses are to be such that the transverses, in association with the effective area of shell and bulkhead plating (*see* D 5304), have a section modulus not less than that given by 7012.

Decks

7015 The thickness of deck plating is to be determined from the requirements of 7002 but is to be not less than the minimum thickness as determined from D 403.

7016 The scantlings of beams or longitudinals are to be obtained from D 8 and D 6.

7017 The section modulus of deck transverses is to be as required by D 13.

Transverse Bulkheads

7018 The scantlings of single transverse watertight bulkheads are to be determined from D 18.

7019 Where the transverse bulkheads are arranged as floodable cofferdams (*see* D 7103) the scantlings of the bulkheads are to be in accordance with D 19.

Cross-references

7020 For filling, discharging and venting pipe arrangements, *see* E 12.

For electrical installations, *see* M 16.

For refrigerating machinery and arrangements, *see* E 12.

For the use of methane gas as fuel for propulsion purposes, *see* R (A).

Section 71

CARRIAGE AT A PRESSURE OF 0,70 kg/cm² (10 lb/in²) GAUGE OR LESS

Submission of Plans

7101 In addition to those required by D 109 the following plans are to be submitted:—

Scantlings of cargo tanks.

Details of tank supports and keying arrangements.

Fire extinguishing arrangements.

The following should also be submitted:—

Calculations for dynamic loading of cargo tanks (*see* 7116).

Specification for tank material including results of low temperature tests.

Ship's Structure

7102 Vessels are to have a double bottom and, where the cargo is to be carried at a temperature below −10°C (+14°F), are generally to be provided with two longitudinal bulkheads forming side tanks.

7103 Cofferdams are to be arranged at each end of the tank space. Other transverse bulkheads are to be arranged as floodable cofferdams when the minimum cargo temperature is below −50°C (−58°F).

7104 When the minimum cargo temperature is below −10°C (+14°F) a secondary barrier is to be provided which will act as a temporary containment for the liquefied gas in the event of a leakage from the containers.

Provided the minimum cargo temperature is not below −50°C (−58°F) this containment may be provided by the hull structure, but with this arrangement the grades of steel in the containing hull structure are to be dependent on the minimum steel temperatures which may arise in the event of leakage from the cargo tanks, as follows:—

Down to −10°C (+14°F) ...	... Grade A
−10°C (+14°F) to −30°C (−22°F)	... Grade D
−30°C (−22°F) to −50°C (−58°F)	... Grade E

7105 The insulation arrangements are to be such that the minimum steel temperature in the hull structure adjacent to the cargo tanks does not fall below the following values when the cargo tanks are at the minimum service temperature and the air temperature is 5°C (+41°F):—

Grade A ...	0°C (+32°F)
Grade D ...	−12°C (+10°F)
Grade E ...	−18°C (0°F)

7106 Where a secondary barrier separate from the hull structure is provided the following requirements are to be met:—

(*a*) The minimum hull steel temperatures, in the event of leakage from the cargo tanks, shall be not less than those given in 7104 for the particular grade of steel.

(*b*) Thermo-couples are to be arranged on the ship's structure adjacent to the cargo tanks and the arrangements are to be such as to give continuous temperature readings and audible warning of the development of temperatures lower than given in 7104. In general, such thermo-couples are to be arranged not more than 6,1 m (20 ft) apart.

(*c*) The extent of the secondary barrier is to be such that the liquefied gas will not come into contact with the hull structure in the event of failure of one cargo tank with the ship heeled to an angle of 30°.

(*d*) The secondary barrier shall be capable of containing the liquefied gas for a period of at least 14 days.

7107 Arrangements are to be provided to enable the double bottom, wing tank spaces and all transverse cofferdams (where fitted) to be flooded in the event of leakage from the cargo tanks.

7108 Suitable arrangements are to be made for sealing the weather deck in way of openings for the cargo tanks.

7109 Any means of access to the spaces around the cargo tanks is to be from above the weather deck.

7110 The spaces containing the cargo tanks are to be permanently filled with an inert gas and a monitoring system is to be installed to ensure that any leakage from the tank is immediately detected.

7111 Arrangements are to be provided to prevent excessive pressure coming on to the containment spaces either during service or in the event of leakage from the cargo tanks.

Cargo Tanks

7112 The material to be used in the construction of the cargo tanks must have suitable mechanical properties at the service temperature. Particulars of the material proposed are to be submitted for approval.

7113 Where a ferritic steel is to be used, tensile, bend and Charpy V-notch impact test pieces are to be prepared from each plate or section. The dimensions of the test pieces are to be in accordance with the requirements contained in P 203, P 204, P 206 and P 207.

The results of the tensile and bend tests are to comply with the approved specification. For the Charpy V-notch impact tests the "required temperature" is the lowest service temperature and the results of the tests are to give an average energy for fracture of not less than 5,53 kg m (40 ft lb).

Other criteria and methods of testing will be accepted where considered equivalent to the above requirements.

7114 It is to be demonstrated by procedure tests that the proposed methods of welding are satisfactory and produce sound welds. Charpy V-notch impact test pieces are to be prepared from butt welded test plates and are to be

notched in the heat-affected zone and, if the deposited metal is a ferritic steel, further test pieces are to be notched in the weld. Unless otherwise approved, the results of the impact tests on these test pieces at the minimum temperature of service are to be not less than those specified for the parent material.

7115 For materials other than ferritic steels, the proposed material specification is to be submitted. The notched properties as determined by suitable tests and/or evidence of comparable service experience, at temperatures lower than or equal to the minimum service temperature are also to be submitted, together with corresponding data on the weld metal and heat-affected zone.

7116 The tanks shall be designed to withstand:—

(i) A test head of 2,44 m (8 ft) of water above the top of the tank or 0,61 m (2 ft) above the top of the hatch, whichever may be the greater.

(ii) The combined effect of internal vapour pressure (if any) and rolling, pitching and heaving as follows:—

(1) A complete 30° roll port and starboard (i.e. through 120°) in a period of ten seconds.

(2) A pitch of 6° half amplitude in a pitch period of seven seconds (i.e. through 24° in seven seconds).

(3) A heave of 0,0125L half amplitude in a period of eight seconds (i.e. through 0,05L in eight seconds).

With the loading determined in accordance with the above, the stress in any item shall not exceed three-quarters of the yield stress or three-eighths of the ultimate stress.

7117 Means are to be provided to prevent excessive pressure coming on to the tanks (*see* E 12).

7118 The tanks are to be supported on substantial foundations arranged to avoid excessive concentration of load on the ship's structure or on the tank. Provision is to be made for the thermal contraction of the tanks on cooling from ambient to service temperature and arrangements are to be made to control the movement of the tanks when the vessel is rolling and pitching.

7119 The arrangement of tanks and insulation is to be such that at least one side of the tank plating and adjacent hull structure is readily accessible for inspection.

7120 During the construction of the tanks all butt welds are to be radiographed.

7121 The tanks are to be tested on completion with a head of water in accordance with 7116 (i).

7122 Thermo-couples are to be fitted to at least one tank to enable a satisfactory pre-cooling procedure to be established unless other satisfactory arrangements can be made.

Insulation

7123 The insulation is to be of an approved type and of sufficient thickness to comply with 7105 of these requirements. It is to be suitable for the loads imposed and adequately protected against penetration of water vapour from the atmosphere.

Particulars of the insulating material(s) and the estimated heat conductivity value(s) at the service conditions are to be supplied, together with the proposed thickness(es) and methods of fitting, jointing and sealing the insulation.

Section 72

CARRIAGE AT A PRESSURE ABOVE 0,70 kg/cm^2 (10 lb/in^2) GAUGE (WITH OR WITHOUT REFRIGERATION PLANT)

Submission of Plans

7201 In addition to those required by D 109 the following plans are to be submitted:—

Cargo Tank Seatings and Securing Arrangements.

Hold Ventilation System.

Fire Extinguishing Arrangements.

Ship's Structure

7202 Where the cargo is to be carried at a temperature below ambient the requirements of D 7104 and D 7105 are to be complied with.

7203 Cofferdams, or single bulkheads of all-welded construction forming an "A" class fire-resisting division, are to be arranged between spaces containing the cargo tanks and machinery spaces.

Installation of Cargo Tanks

7204 Cargo tanks are to be sited so that the following minimum clearances are obtained:—

(*a*) Tanks to the side shell—generally 610 mm (24 in), but clearances at the ends of the ship below the load waterline will be specially considered.

(*b*) Tanks to inner bottom plating—150 mm (6 in).

(*c*) Tanks to bottom shell (if no inner bottom is fitted)—not less than the depth of centre girder given by D 904.

Where more than one tank is fitted in a space, sufficient clearance is to be left between tanks for inspection or repairs and in no case less than 300 mm (12 in).

7205 Cargo tank seatings and securing arrangements are to be suitable for dynamic loading to the extent given in D 7116 and should also be suitable for the forces arising when a cargo hold is flooded with the cargo tanks empty. Seatings are to be designed to ensure uniform support to the pressure vessel having due regard to deflections of the hull structure in a seaway. When the cargo is to be carried at temperatures below ambient, provision is to be made for expansion and contraction.

7206 The supports and securing arrangements should also be capable of withstanding a longitudinal acceleration of 0,5 g.

7207 Suitable arrangements are to be made for sealing the weather deck in way of openings for the cargo tanks.

7208 The spaces containing the cargo tanks are to be provided with means for access from above the weather deck.

7209 Ventilation systems for the spaces containing cargo tanks are to be independent of other ventilation systems, and means are to be provided to enable any single compartment to be isolated. Details, including the positioning of exhaust outlets, are to be submitted.

7210 Means are to be provided to enable the air in the cargo tank spaces, pump and compressor rooms to be sampled to detect any leakage.

Cross-reference

7211 For cargo tanks and their mountings *see* J 7 and E 12.

16th January, 1969

Chapter E

PUMPING AND PIPING

Section 1

PLANS

101 The following plans are to be submitted for consideration:—

General pumping arrangements, including air and sounding pipes and any cross flooding pipes and fittings. (Shipbuilder's plan.)

Pumping arrangements at the forward and after ends of oil tankers and drainage of cofferdams and pump rooms.

General arrangement of cargo piping in tanks and on deck of oil tankers.

Piping arrangements for cargo oil (F.P. above 65,5°C (150°F)).

Bilge, ballast and oil fuel pumping arrangements in the machinery space, including the capacities of the pumps on bilge service. In the case of passenger ships the criterion numeral, as defined in the International Convention for the Safety of Life at Sea–1960 is to be stated together with the number of flooded compartments which the ship is required to withstand under damage conditions.

Arrangement of oil fuel pipes and fittings at settling and service tanks.

Arrangements of oil fuel piping in connection with oil burning installations and oil fired galleys.

Oil fuel and cargo oil overflow systems, where these are fitted.

Arrangement of boiler feed system.

Arrangement of compressed air systems for main and auxiliary essential services.

Arrangement of cooling water systems for main and auxiliary essential services.

Oil fuel settling, service and other oil fuel tanks not forming part of the ship's structure.

Above plans of piping are to be diagrammatic.

Arrangement and dimensions of main steam pipes with details of flanges, bolts and weld attachments and particulars of the material of pipes, flanges bolts and electrodes.

NOTE.—Plans additional to the above should not be submitted unless the arrangements are of a novel or special character affecting classification.

See Chapter L for Control Engineering Equipment.

See Chapter R(B) for Provisional Rules for Plastic Pipes.

See Chapter R(D) for Guidance Notes on Metal Pipes for Water Services.

Section 2

GENERAL

201 In power driven ships the pumping arrangements according to the division of compartments, rise of floor and other conditions are to be as detailed in these Rules which apply to passenger ships, cargo and other ships except where otherwise stated.

202 While the arrangements satisfy the requirements of the International Convention for the Safety of Life at Sea–1960, attention should be given to any relevant statutory requirements of the National Authority of the country in which the ship is to be registered.

203 The Committee will be prepared to give consideration to special cases or to arrangements which are fully equivalent to those required by these Rules. Consideration will also be given to the pumping arrangements of small ships and ships to be assigned class notations for restricted or special services.

(For pumping arrangements of non-propelled ships, *see* E 10.)

BILGE AND BALLAST

204 All ships are to be provided with efficient pumping plant having the suctions and means for drainage so arranged that any water within any compartment of the ship, or any watertight section of any compartment, can be pumped out through at least one suction when the ship is on an even keel and is either upright or has a list of not more than 5 degrees. For this purpose wing suctions will generally be necessary, except in short, narrow compartments where one suction can provide effective drainage under the above conditions.

In passenger ships the pumping plant is to be capable of draining any watertight compartment under all practical conditions after a casualty, whether the ship is upright or listed.

Hold Drainage

205 In ships having only one hold, and this over 33,5 m (110 ft) in length, bilge suctions are to be fitted in suitable positions in the after half-length, also in the forward half-length of the hold.

206 Where close ceiling or continuous gusset plates are fitted over the bilges, arrangements are to be made whereby water in a hold compartment may find its way to the suction pipes.

207 Where the inner bottom plating extends to the ship's side, the bilge suctions are to be led to wells placed at the wings. If the tank top plating has inverse camber, a well is also to be fitted at the centre line.

Bilge wells are to be formed of steel plates and are not to be less than 0,17 m^3 (6 ft^3) capacity. In small compartments, steel bilge hats of reasonable capacity may be fitted.

In passenger ships wells in double bottom tanks are not to extend downwards more than necessary; the depth of the well is in no case to be more than the depth less 460 mm (18 in) of the double bottom at the centre line, nor shall the well extend below the horizontal plane referred to in D 909.

Where access manholes to bilge wells are necessary, they are to be fitted as near to the suction strums as practicable.

208 Access to the bilge suction strum of a hold well should not be obtained by means of a manhole in the machinery space watertight bulkheads or tank top plating in the machinery space or tunnel if this can be avoided.

Where, however, this arrangement is necessary, the watertight manhole cover should be of hinged type and an instruction plate, in raised letters, should be affixed in a well lighted position, to the effect that this door must be kept shut, except when access is required. In passenger ships these arrangements are not permissible.

209 The intactness of the machinery space bulkheads, and of tunnel plating which is required to be of watertight construction, is not to be impaired by the fitting of scuppers discharging to machinery space or tunnels from adjacent compartments which are situated below the bulkhead deck.

These scuppers may, however, be led into a strongly constructed scupper drain tank situated in the machinery space or tunnel but closed to these spaces and drained by means of a suction of appropriate size led from the main bilge line through a screw-down non-return valve.

The tank air pipe is to be led to above the bulkhead deck and provision is to be made for ascertaining the level of water in the tank.

Where one tank is used for the drainage of several watertight compartments, the scupper pipes are to be provided with screw-down non-return valves.

210 Steering gear compartments or other small enclosed spaces situated above the after peak tank are to be provided with suitable means of drainage either by hand or power pump bilge suctions.

If, however, these compartments are adequately isolated from the adjacent 'tween decks, they may be drained by scuppers not less than 38 mm (1·5 in) bore, discharging to the tunnel and fitted with self-closing cocks situated in well lighted and visible positions. These arrangements are not applicable to passenger ships unless specially approved in relation to sub-division considerations.

Drainage from Refrigerated Cargo Spaces

211 Provision is to be made for the continuous drainage of the inside of all insulated chambers and cooler trays.

212 Drains which are led from lower holds and cooler trays situated on the tank top are to be fitted with liquid sealed non-return bilge traps.

Drains from 'tween deck chambers and from cooler trays which are situated well above the tank top are also to be fitted with liquid sealed traps, but the non-return valves may be omitted if desired. (For insulation of scupper pipes, *see* E 418.)

213 Where drains from separate chambers join a common main, the branch pipes are each to be provided with a liquid sealed trap.

214 The liquid sealed traps are to be of adequate depth and arrangements are to be made for ready access to the traps for cleaning and refilling with brine.

215 Sluices, scuppers or drain pipes which would permit drainage from compartments outside the insulated chambers into the bilges of the latter are not to be fitted.

216 Screwed plugs or other means for blanking off scuppers draining insulating chambers and cooler trays are not to be fitted.

If, however, it is specially desired by the Owners to provide means for temporarily closing these scuppers, they may be fitted with shut-off valves controlled from readily accessible positions on a deck above the load water line.

Machinery Space—Bilge Drainage

217 The bilge drainage arrangements in the machinery space are to be such that any water which may enter this compartment can be pumped out through at least two bilge suctions when the ship is on an even keel and is either upright or has a list of not more than 5 degrees. One of these suctions is to be a branch bilge suction, i.e., a suction connected to the main bilge line, and the other is to be led direct from an independent power pump. Examples of the necessary arrangements are detailed in 218 to 220.

In passenger ships the drainage arrangements are to be such that machinery spaces can be pumped out under all practical conditions after a casualty whether the ship is upright or listed.

Where it is intended that the engine and/or boiler rooms will not be continuously manned at sea, an approved bilge level alarm system is to be provided in these spaces to give warning of flooding (*see* L 207). The alarm system is to operate audible and visible signals at the station from which the machinery is controlled which should be in direct communication with the bridge. When control is being effected from the bridge only, the alarms must operate in the engine room control station and in the Engineer Officers' accommodation.

218 Where the double bottom extends the full length of the machinery space and forms bilges at the wings, it will be necessary to provide one branch and one direct bilge suction at each side.

219 Where the double bottom plating extends the full length and breadth of the compartment, one branch bilge suction and one direct bilge suction are to be led to each of two bilge wells of not less than 0,17 m^3 (6 ft^3) capacity, situated one at each side.

In passenger ships the depth of bilge wells is to comply with the requirements of 207.

220 Where there is no double bottom and the rise of floor is not less than 5 degrees, one branch and one direct bilge suction are to be led to accessible positions as near the centre line as practicable.

In ships where the rise of floor is less than 5 degrees and in all passenger ships additional bilge suctions are to be provided at the wings.

221 Additional bilge suctions may be required for the drainage of depressions in the tank top formed by crank pits, or other recesses, by tank tops having inverse camber or by discontinuity of the double bottom.

222 In ships in which the propelling machinery is situated at the after end of the ship, it will generally be necessary for bilge suctions to be fitted in the forward wings as well as the after end of the machinery space, but each case will be dealt with according to the size and structural arrangements of the compartment.

223 In ships propelled by electrical machinery, special means are to be provided to prevent the accumulation of bilge water under the main propulsion generators and motors.

224 Where the machinery space is divided by watertight bulkheads to separate the boiler room(s) or auxiliary engine room(s) from the main engine room, the number and position of the branch bilge suctions in the boiler room(s) and auxiliary engine room(s) are to be the same as for cargo holds.

In addition to the branch bilge suctions an independent power pump direct bilge suction is to be fitted in each compartment. Similar provision is to be made in separate motor rooms of electrically propelled ships.

225 In passenger ships each independent bilge pump is to have a direct bilge suction from the space in which it is situated, but not more than two such suctions are required in any one space. Where two or more such suctions are provided there is to be at least one suction on each side of the space.

Machinery Space—Emergency Bilge Drainage

226 In steamers, the main circulating water pump to each main engine is to be fitted with an emergency bilge suction, i.e., "bilge injection", which is to be additional to the bilge suctions detailed in 217 to 225. This suction, which is to have a diameter of at least two-thirds that of the pump suction, is to be led to a suitable low level in the machinery space and is to be fitted with a screw-down non-return valve having the spindle so extended that the hand-wheel is not less than 460 mm (18 in) above the bottom platform.

If two pumps are provided for one engine, each capable of supplying sufficient cooling water for normal power, only one pump need be fitted with an emergency bilge suction.

Where main circulating water pumps are not suitable for bilge pumping duties, alternative arrangements may be submitted for consideration.

227 In motorships, the emergency bilge suction is to be led to the main cooling water pump or to the main cooling water suction line. The suction is to be of the same size as the suction branch of the cooling water pump and the valve nameplate is to be marked "For emergency use only".

Alternatively, the emergency bilge suction may be led to the largest available power pump which is not fitted with a direct bilge suction and is to be of the same size as the suction branch of the pump. This pump is to have a capacity greater than that required for a bilge pump, and if it is of the self-priming type the direct bilge suction on the same side of the ship as the emergency suction may be omitted, except in passenger ships.

This emergency bilge suction is additional to the bilge suctions detailed in 217 to 225 and is to comply with the requirements of 226 as regards location and valve arrangements.

Tunnel Drainage

228 The tunnel well is to be drained by a suction from the main bilge line. In all ships including passenger ships this well may extend to the outer bottom.

229 Where the tank top in the tunnel slopes down from aft to forward, a bilge suction is to be provided at the forward end of the tunnel, in addition to the tunnel well suction required by 228.

Sizes of Bilge Suction Pipes

230 The diameters of bilge suction pipes are not to be less than required by the following formulæ, to the nearest 5 mm (0·25 in):—

MAIN BILGE LINE

$$d_m = \sqrt{2{,}78\,L\,(B + D)} + 26 \text{ mm} \quad (1)$$

$$\left(d_m = \sqrt{\frac{L\,(B + D)}{2500}} + 1 \text{ in}\right)$$

In no case is the diameter of the main bilge line to be less than required for any branch bilge suction.

BRANCH BILGE SUCTIONS TO CARGO AND MACHINERY SPACES

$$d_b = \sqrt{4{,}63\,C\,(B + D)} + 26 \text{ mm} \quad (2)$$

$$\left(d_b = \sqrt{\frac{C\,(B + D)}{1500}} + 1 \text{ in}\right)$$

where d_m = internal diameter of main bilge line, in mm (in),

d_b = internal diameter of branch bilge suction, in mm (in),

L = Rule length of ship, in metres (feet),

B = Rule breadth of ship, in metres (feet),

D = moulded depth to bulkhead deck, in metres (feet),

C = length of compartment, in metres (feet).

No bilge suction pipe is, however, to be less than 50 mm (2 in) bore.

DIRECT BILGE SUCTIONS, OTHER THAN EMERGENCY SUCTIONS

231 The direct bilge suctions in the main engine room and the direct bilge suctions in large separate boiler rooms, motor rooms of electrically propelled ships and auxiliary engine rooms are not to be of a diameter less than required for the main bilge line.

Where the separate machinery spaces are of small dimensions, the sizes of the direct bilge suctions to these spaces will be specially considered.

For sizes of emergency bilge suctions, *see* 226 and 227.

232 In oil tankers and similar ships where the engine room pumps do not deal with bilge drainage outside the machinery space, the diameter of the main bilge line may be less than required by formula 230 (1), provided the cross-sectional area is not less than twice that required for the branch bilge suctions in the machinery space.

233 The area of each branch pipe connecting the bilge main to a bilge distribution chest is not to be less than the sum of the areas required by the Rules for the two largest branch bilge suction pipes connected to that chest, but need not be greater than that required for the main bilge line.

234 The bilge suction pipe to the tunnel well is not to be less than 65 mm (2·5 in) bore, except in ships not exceeding 61 m (200 ft) in length, in which case it may be 50 mm (2 in) bore.

Bilge and General Service Pumps

235 For ships other than passenger ships at least two power bilge pumping units are to be provided in the machinery space. In ships of 91,5 m (300 ft) in length and under, one of these units may be worked from the main engines and the other is to be independently driven. In larger ships both units are to be independently driven.

Each of these units is to be connected to the main bilge line and is to be capable of giving a speed of water through the Rule size of bilge of not less than 122 m/minute (400 ft/minute) under ordinary working conditions, but where one unit is of slightly less than this capacity, the deficiency may be made good by an excess capacity of the other unit.

236 Table of Capacities

TABLE E 2.1

Bore of bilge pipe mm (in)	Capacity of each pumping unit in m^3/hour or ton/hour	Bore of bilge pipe mm (in)	Capacity of each pumping unit in m^3/hour or ton/hour
51 (2)	15	133 (5·25)	103
57 (2·25)	19	140 (5·5)	113
63,5 (2·5)	23	146 (5·75)	124
70 (2·75)	28	152 (6)	135
76 (3)	34	159 (6·25)	146
82,5 (3·25)	40	165 (6·5)	158
89 (3·5)	46	171 (6·75)	171
95 (3·75)	53	178 (7)	183
102 (4)	60	184 (7·25)	197
108 (4·25)	68	190 (7·5)	210
114 (4·5)	76	197 (7·75)	224
121 (4·75)	84	203 (8)	239
127 (5)	93	209 (8·25)	254

237 Each unit may consist of one or more pumps connected to the main bilge line, provided their combined capacity is adequate.

238 In ships other than passenger ships a bilge ejector in combination with a high pressure sea water pump may be accepted as a substitute for an independent bilge pump required by 235.

239 For passenger ships at least three power bilge pumps are to be provided, one of which may be operated from the main engines. Where the criterion numeral is 30 or more, one additional independent power pump is to be provided. A main engine driven pump may be replaced by an independent pump. Each pump is to be connected to the main bilge line and is to be capable of giving a speed of water through the Rule size of main bilge pipe of not less than 122 m/minute (400 ft/minute).

For location of pumps, *see* 256.

Self-Priming Pumps

240 All power pumps which are essential for bilge services are to be of self-priming type, unless an approved central priming system is provided for these pumps. Details of this system are to be submitted.

Cooling water pumps having bilge ejection connections need not be of self-priming type.

Pump Connections

241 The connections at the bilge pumps are to be such that one unit may continue in operation when the other unit is being opened up for overhaul.

242 Pumps required for essential services are not to be connected to a common suction or discharge chest or pipe unless the arrangements are such that the working of any of the pumps so connected is unaffected by the other pumps being in operation at the same time.

Direct Bilge Suctions

243 The direct bilge suctions in the machinery space(s) are to be led to independent power pump(s), and the arrangements are to be such that these direct suctions can be used independently of the main bilge line suctions.

Main Bilge Line Suctions

244 Suctions from the main bilge line, i.e., branch bilge suctions, are to be arranged to draw water from any hold or machinery compartment of the ship, excepting small spaces such as those mentioned in 262, where manual pump suctions are accepted, and are to be of not less size than required by formula 230 (2). (For special arrangements for oil tankers, *see* E 1112 to E 1117).

Pipe Systems and their Fittings

245 The arrangement of valves, cocks and their connections is to be such as to prevent the possibility of one watertight compartment being placed in communication with another, or of dry cargo spaces, machinery spaces or other dry compartments being placed in communication with the sea or with tanks.

To effect this requirement, the bilge connections to any pump having also suctions from the sea and from tanks should be made either by means of non-return valves or cocks which cannot permit communication between the bilges and the sea or compartments in use as tanks.

246 Screw-down non-return valves are to be provided in the following fittings:—

Bilge valve distribution chests;

Bilge suction hose connections, whether fitted direct to the pump or on the main bilge line;

Direct bilge suctions and bilge pump connections to main bilge line.

247 Bilge pipes which are required for draining cargo or machinery spaces are to be entirely distinct from sea inlet pipes or from pipes which may be used for filling or emptying spaces where water or oil is carried. This does not, however, exclude a bilge ejection connection, a connecting pipe from a pump to its suction valve chest, or a deep tank suction pipe suitably connected through a change-over device to either a bilge, ballast or oil line.

248 Suctions for bilge drainage in machinery spaces and tunnels, other than emergency suctions, are to be led from easily accessible mud boxes fitted with straight tail pipes to the bilges and having covers secured in such a manner as to permit their being expeditiously opened or closed. Strum boxes are not to be fitted to the lower ends of these tail pipes.

249 The open ends of bilge suctions in holds and other compartments outside machinery spaces and tunnels, are to be enclosed in strum boxes having perforations not more than 10 mm (0·375 in) diameter, whose combined area is not less than twice that required for the suction pipe. The boxes are to be so constructed that they can be cleared without breaking any joint of the suction pipe.

The distance between the foot of all bilge tail pipes and the bottom of the bilge or well is to be adequate to allow a full flow of water and to facilitate cleaning.

250 All valves and cocks in connection with bilge, ballast and fresh water suction pipes are to be fitted with legible nameplates, and, unless otherwise specifically mentioned in the Rules, are to be fitted in places where they are at all times readily accessible.

251 Bilge valves, cocks and mud boxes are to be fitted at, or above, the machinery space and tunnel platforms.

Where it is not practicable to avoid the fittings being situated at the starting platform or in passageways, they may be situated just below the platform, provided readily removable traps or covers are fitted and nameplates indicate the presence of these fittings.

If relief valves are fitted to pumps having sea connections, these valves are to be fitted in readily visible positions above the platform.

252 Bilge suction pipes are not to be carried through double bottom tanks if it is possible to avoid doing so.

Bilge pipes which pass through these tanks are to be of substantial strength and are to be tested, after fitting, to the same pressure as the tanks through which they pass.

253 In way of deep tanks for water ballast, fresh water, oil fuel or cargo oil, bilge pipes should preferably be led through pipe tunnels but, where this is not done, the pipes are to be of steel of heavy gauge with welded joints or heavy flanged joints. The number of joints is to be kept to a minimum.

Expansion bends, not glands, are to be fitted to these pipes within the tanks, and the open ends of the bilge suction pipes in the holds are to be fitted with non-return valves of the special type approved for use in holds (*see* 266).

Tank piping, other than that of the deep cargo tank pumping system, is not to be situated within deep cargo oil tanks.

The pipes are to be tested, after fitting, to a pressure not less than the maximum head to which the tanks can be subjected.

254 Bilge, ballast and cooling water suction and discharge pipes are to be permanent pipes made in readily removable lengths with flanged joints, except as mentioned in 253, and are to be efficiently secured in position to prevent chafing or lateral movement.

Where lack of space prevents the use of normal circular flanges, details of the alternative methods of joining the pipes are to be submitted.

Long or heavy lengths of pipes are to be supported by bearers so that no undue load is carried by the flanged connections of the pumps or fittings to which they are attached.

Pipes for bilge, ballast and cooling water systems are to be made of cast iron, steel, copper or other approved material. Heat sensitive materials such as lead are not to be used.

255 Suitable provision for expansion is to be made in each range of pipes.

Expansion pieces of an approved type incorporating special quality oil resistant rubber or other suitable synthetic material may be used in cooling water lines in machinery spaces. Where fitted in sea water lines, they are to be provided with guards which will effectively enclose, but not interfere with, the action of the expansion pieces and will reduce to the minimum practicable any flow of water into the machinery spaces in the event of failure of the flexible elements.

Proposals to use such fittings in water lines for other services, including:—

(*a*) ballast lines in machinery spaces, duct keels and inside double bottom water ballast tanks,

(*b*) bilge lines inside duct keels only,

will be specially considered when plans of the pumping systems are submitted for consideration.

Bilge Drainage and Cross Flooding Arrangements for Passenger Ships in Damaged Condition

256 In passenger ships the power bilge pumps are, if practicable, to be placed in separate watertight compartments which will not readily be flooded by the same damage. If the engines and boilers are in two or more watertight compartments, the bilge pumps are to be distributed throughout these compartments as far as possible.

In passenger ships of 91,5 m (300 ft) or more in length or having a criterion numeral of 30 or more, the arrangements are to be such that at least one power pump will be available for use in all ordinary circumstances in which the ship may be flooded at sea. This requirement will be satisfied if:—

(*a*) One of the pumps is an emergency pump of a submersible type having a source of power situated above the bulkhead deck or,

(*b*) The pumps and their sources of power are so disposed throughout the length of the ship that, under any conditions of flooding which the ship is required by statutory regulation to withstand, at least one pump in an undamaged compartment will be available.

257 The bilge main is to be arranged so that no part is situated nearer the side of the ship than $\frac{B}{5}$ where B is the breadth of the ship.

Where any bilge pump or its pipe connection to the bilge main is situated outboard of the $\frac{B}{5}$ line then a non-return valve is to be provided in the pipe connection at the junction with the bilge main. The emergency bilge pump and its connections to the bilge main are to be arranged so that they are situated inboard of the $\frac{B}{5}$ line.

258 Provision is to be made to prevent the compartment served by any bilge suction pipe being flooded in the event of the pipe being severed, or otherwise damaged by collision or grounding in any other compartment. For this purpose, where the pipe is at any part situated nearer the side of the ship than $\frac{B}{5}$ or in a duct keel, a non-return valve is to be fitted to the pipe in the compartment containing the open end.

259 All the distribution boxes, valves and cocks in connection with the bilge pumping arrangements are to be so arranged that, in the event of flooding, one of the bilge pumps may be operative on any compartment. If there is only one system of pipes common to all pumps, the necessary valves or cocks for controlling the bilge suctions must be capable of being operated from above the bulkhead deck. Where in addition to the main bilge pumping system an emergency bilge pumping system is provided, it is to be independent of the main system and so arranged that a pump is capable of operating on any compartment under flooding conditions; in this case only the valves and cocks necessary for the operation of the emergency system need be capable of being operated from above the bulkhead deck.

260 All valves and cocks mentioned in the foregoing paragraphs which can be operated from above the bulkhead deck are to have their controls at their place of operation clearly marked and provided with means to indicate whether they are open or closed.

261 Where divided deep tanks or side tanks are provided with cross flooding arrangements to limit the angle of heel after side damage, the arrangements are either to be self acting or controlled from above the bulkhead deck.

Fore and After Peak Drainage

262 Where the peaks are used as tanks, a power pump suction is to be led to each tank, except in the case of small tanks used for the carriage of domestic fresh water, when hand pumps may be used.

The collision bulkhead is not to be pierced below the bulkhead deck in passenger and cargo ships by more than two pipes. The pipes are to be provided with screw-down valves capable of being operated from an accessible position above the bulkhead deck, the chests being secured to the bulkhead inside the fore peak. Indicators are to be provided to show whether the valves are open or shut.

Where the peaks are not used as tanks and main bilge line suctions are not fitted, drainage of both peaks may be effected by hand pump suctions, provided the suction lift be well within the capacity of the pumps and in no case exceeds 7,3 m (24 ft).

Provision is to be made for the drainage of the chain locker and the watertight flat above the fore peak tank by hand or power pump suction. (For drainage of the flat above the after peak tank, *see* 210.)

Watertight Bulkhead and Tunnel Fittings

263 No drain valve or cock is to be fitted to the collision bulkhead.

Drain valves or cocks are not to be fitted to other watertight bulkheads, if alternative means of drainage are practicable.

Where fitted, the valves and cocks are to be at all times readily accessible and are to be capable of being shut off from positions above the bulkhead deck. Indicators are to be provided to show whether the drains are open or shut. These arrangements are not permissible in passenger ships. (For drainage of stern compartments, *see* 210.)

264 Valve chests, cocks, pipes or other fittings attached direct to the plating of tanks, and to bulkheads, flats or tunnels which are required to be of watertight construction, are to be secured by means of studs screwed through the plating or by tap bolts and not by bolts passing through clearance holes.

Alternatively, the studs or the bulkhead piece may be welded to the plating.

Deep Tanks

265 In the case of deep tanks which may be used for either water ballast or dry cargo, provision is to be made for blank flanging the water ballast filling and suction pipes when the tank is being used for the carriage of dry cargo and for blank flanging the bilge suction pipes when the tank is being used for the carriage of water ballast.

Change-over devices may be used for this purpose. (For arrangements when oil fuel or cargo oil is carried in deep tanks, *see* E 324.)

Hold Bilge Valves

266 Where non-return valves are fitted to the open ends of bilge suction pipes in cargo holds in order to decrease the risk of flooding, they are to be of an approved type which does not offer undue obstruction to the flow of water.

Ship-Side Valves and Fittings (other than those on Scuppers and Sanitary Discharges)

267 All sea inlet and overboard discharge pipes are to be fitted with valves or cocks secured direct to the shell plating or to the plating of fabricated steel water boxes attached to the shell plating. These fittings are to be secured by bolts tapped into the plating and fitted with countersunk heads or by studs screwed into heavy steel pads fitted to the plating. The stud holes are not to penetrate the plating.

Distance pieces of short rigid construction, and made of approved material as required by 270, may be fitted between the valves and shell plating. Distance pieces of steel may be welded to the shell plating. Details of the welded connections and of fabricated steel water boxes are to be submitted.

Gratings are to be fitted at all openings in the ship's side for sea inlet valves and inlet water boxes. The net area through the gratings is not to be less than twice that of the valves connected to the sea inlets and provision is to be made for clearing the gratings by use of low pressure steam or compressed air. (*See* 271.)

268 All suction and discharge valves and cocks secured direct to the shell plating of the ship are to be fitted with spigots passing through the plating, but the spigots on the valves or cocks may be omitted if these fittings are attached to pads or distance pieces which themselves form spigots in way of the shell plating.

Blow-down valves or cocks are also to be fitted with a protection ring through which the spigot is to pass, the ring being on the outside of the shell plating.

269 Blow-down valves or cocks on the ship's side are to be fitted in accessible positions above the level of the working platform and are to be provided with indicators showing whether they are open or shut. Cock handles are not to be capable of being removed unless the cocks are shut, and if valves are fitted, the hand wheels are to be suitably retained on the spindle.

Sea inlet and overboard discharge valves and cocks are in all cases to be fitted in easily accessible positions and, as far as practicable, are to be readily visible. Indicators are to be provided local to the valves and cocks, showing whether they are open or shut.

Provision is to be made for preventing any discharge of water into lifeboats.

The inlet valve spindles are to extend above the lower platform, and the hand wheels of the main injection and bilge injection valves are not to be situated less than 460 mm (18 in) above this platform.

270 All valves and cocks are to be of steel, bronze or other approved ductile material; ordinary cast iron is not acceptable. This requirement applies equally to inlet chests, distance pieces and other sea connections.

All these fittings, if made of steel, are to be suitably protected against wastage.

271 The scantlings of valves and valve stools fitted with steam or compressed air clearing connections are to be suitable for the maximum pressure to which the valves and stools may be subjected.

Cross-reference

272 For sea connections for ships having notation for ice navigation, *see* H 509 to H511.

Miscellaneous Requirements

273 All pipes situated in cargo spaces, chain lockers or other positions where they are liable to mechanical damage are to be efficiently protected. (*See* D 2819, quoted at end of this Section, and D 2914, quoted at end of E 4.)

274 Wash deck pipes and discharge pipes from the pumps to domestic water tanks are not to be led through cargo holds if, as is generally the case, it is practicable to avoid doing so. Any proposed departure from this requirement is to be submitted.

275 As far as practicable, pipe lines, including exhaust pipes from oil engines, are not to be led in the vicinity of switchboards or other electrical appliances in positions where drip or escape of liquid, gas or steam from joints or fittings may cause damage to the electrical installation.

Where it is not practicable to comply with these requirements, drip trays or shields are to be provided as found necessary.

Short sounding pipes to tanks should not terminate near electrical appliances. (*See* E 413.)

Extract from Chapter D for reference

Scuppers and Sanitary Discharges

D 2811 Scuppers sufficient in number and size to provide effective drainage are to be fitted in all decks.

D 2812 In ships over 150 m (492 ft) in length, scupper openings are not to be cut in the sheerstrake above deck level within 0,5L amidships, and in no case in way of discontinuities such as breaks of superstructures. (*See* D 510.)

When scuppers or discharges are cut in the shell or superstructure sides compensation may require to be fitted.

D 2813 Scuppers and discharges which drain spaces below the freeboard deck or spaces within intact superstructures or deckhouses on the freeboard deck fitted with efficient weathertight doors, may be led to the bilges in the case of scuppers or to suitable sanitary tanks in the case of sanitary pipes. Alternatively, they may be led overboard provided the spaces drained are above the load waterline, and the pipes are fitted with efficient and accessible means of preventing water from passing inboard. (*See* 2814.)

D 2814 In general, each separate overboard discharge is to be fitted with a screw-down non-return valve capable of being operated from a position always accessible and above the freeboard deck. An indicator is to be fitted at the control position showing whether the valve is open or closed.

Where, however, the vertical distance from the summer load waterline to the inboard end of the discharge pipe exceeds 0,01L the discharge may be fitted with two automatic non-return valves without positive means of closing, instead of the screw-down non-return valve, provided the inboard valve is always accessible for examination under service conditions.

Where the vertical distance from the summer load waterline to the inboard end of the discharge pipe exceeds 0,02L, consideration will be given to proposals for fitting a single automatic non-return valve without positive means of closing.

D 2815 Scuppers and discharge pipes originating at any level, which penetrate the shell more than 450 mm (17·5 in) below the freeboard deck or less than 600 mm (23·5 in) above the summer load waterline are to be fitted with an automatic non-return valve at the shell.

This valve, unless required by 2813, may be omitted provided the pipe thickness is not less than:—

$$\frac{\text{Diameter of pipe in mm}}{24} + 6{,}5 \text{ mm}$$

$$\left(\frac{\text{Diameter of pipe in inches}}{24} + 0{\cdot}25 \text{ in}\right)$$

but need not exceed 12,5 mm (0·50 in).

D 2816 Scuppers draining weather decks and spaces within superstructures or deckhouses not fitted with efficient weathertight doors to be led overboard.

D 2817 Plans showing the arrangement of scuppers for draining refrigerated cargo compartments are to be submitted for consideration.

Materials for Valves and Pipes

D 2818 All castings and all elbow pieces where no valves are required, are to be of approved material other than ordinary cast iron or similar non-ductile material.

The lengths of pipe attached to the required valves or elbow pieces are to be of galvanised steel of standard steam pipe quality or other equivalent approved material. (*See also* F 706.)

Protection of Pipes and Valves

D 2819 In all cargo spaces and other areas where damage might be likely, all scuppers and discharges including their valves, controls and indicators are to be well protected. This protection is to be of steel in bulk cargo spaces or their equivalent, and also in areas where contact with large containers, fork lift trucks or similar items is a possibility.

Section 3

OIL FUEL AND CARGO OILS HAVING A FLASH POINT ABOVE 65,5°C (150°F)

General

301 In addition to the special requirements detailed in this Section, the requirements of E 2 relating to bilge and ballast are to be complied with in so far as they are applicable to the drainage of tanks, oil bilges and cofferdams.

302 The flash point (closed test) of oil fuel for use in steam and motor ships classed for unrestricted service is in general not to be less than 65,5°C (150°F). For emergency generator engines a flash point of not less than 43°C (110°F) is permissible.

Fuels with flash points lower than 65,5°C (150°F) may be used in ships intended for service restricted to geographical limits where it can be ensured that the temperature of the machinery and boiler spaces will always be 16,5degC (30degF) below the flash point of the fuel. In such cases, safety precautions and the arrangements for storage and pumping will be specially considered. However, the flash point of the fuel is not to be less than 54°C (130°F) when supplied for oil fired boilers or 43°C (110°F) for oil engines unless specially approved.

When it is desired to carry a quantity of fuel having a flash point below 43°C (110°F) for special services, e.g. aviation spirit for use in helicopters, full particulars of the proposed arrangements are to be submitted for special consideration. For the burning of methane gas in methane tankers, *see* Chapter R(A).

Oil Fuel Pumps and Oil Burning Appliances

303 In every ship where steam for the main propelling engines, or for auxiliary machinery which is required for essential services, is generated by burning oil fuel under pressure, there are to be not less than two oil burning units, each unit comprising a pressure pump, a suction filter, a discharge filter and a heater.

In two unit installations, each unit is to be capable of supplying fuel for generating all the steam required for essential services.

In installations of three or more units, the capacities and arrangements of the units are to be such that all the steam required for essential services can be maintained with any one unit out of action.

304 Unit pressure pumps for the oil burning system are to be entirely separate from the feed, bilge or ballast systems.

305 In systems where oil is fed to the burners by gravity, duplex filters are to be fitted in the supply pipeline to the burners and so arranged that one filter can be opened up when the other is in use. Similar or equivalent arrangements are to be provided in the fuel supply lines to main and auxiliary oil engines and gas turbines.

306 If oil fuel is sprayed by steam, means are to be provided to carry or make up the fresh water used for this purpose.

307 A starting-up oil fuel unit, including an auxiliary heater and hand pump, or other suitable starting-up device, which does not require power from shore, is to be provided.

Alternatively, where auxiliary machinery requiring compressed air or electric power is used to bring the boiler plant into operation, the arrangements for starting such machinery are to comply with H 608.

308 All pumps used in connection with oil fuel are to be provided with effective escape valves which are to be in close circuit, i.e., discharging back to the suction side of the pumps.

Escape valves are also to be fitted on the oil side of the heaters, discharging to the pump suction line, to the tray under the unit, or to other approved positions, and are to be adjusted to operate at a pressure of 3,5 kg/cm^2 (50 lb/in^2) above that of the pump escape valve.

309 Where a power driven transfer pump is necessary for pumping up the settling tanks in motorships and steamships, a stand-by pump is to be provided and connected ready for use, or alternatively, emergency connections may be made to one of the unit pumps or to another suitable power driven pump.

Oil Pipes and Fittings

310 Pipes conveying heated oil under pressure are to be of seamless steel or other approved material having flanged couplings and placed in sight above the platform in well lighted parts of the stokehold or engine room.

The flanges are to be machined and the jointing material, which is to be impervious to oil heated to 150°C (300°F), is to be the thinnest possible, so that the flanges are practically metal to metal. The scantlings of the pipes and their flanges are to be suitable for at least 14 kg/cm^2 (200 lb/in^2) working pressure, or the pressure to which the relief valves are adjusted, whichever is the greater.

The piping system is to be tested after jointing to twice the working pressure.

The thickness of the oil fuel pressure pipes is to be determined from the formulæ contained in E 512 atd E 513.

311 The short joining lengths of pipes to the burners from the control valves at the boiler may have cone unions provided these are of specially robust construction.

Flexible pipes of approved material and design may be used for the burner pipes provided spare lengths, complete with couplings, be carried on board.

A quick-closing master valve is to be fitted to the oil supply to each boiler manifold suitably located so that the valve can be readily operated in an emergency, either directly or by means of remote control, having regard to the machinery arrangements and location of controls.

Provision is to be made by suitable non-return arrangements to prevent oil from spill systems being returned to the burners when the oil supply to these burners has been shut off.

In the case of top-fired boilers, means are to be provided so that, in the event of flame failure, the oil fuel supply to the burners is shut off automatically and audible and visible warning is given. Any proposal to depart from this requirement in the case of small auxiliary top-fired boilers would be the subject of special consideration.

312 **Transfer, suction and other low pressure oil pipes and all pipes passing through oil storage tanks are** to be made of cast iron or steel, having flanged joints suitable for a working pressure of not less than 7 kg/cm^2 (100 lb/in^2). The flanges are to be machined and the jointing material is to be impervious to oil. Where the pipes are 25 mm (1 in) bore, or less, they may be of seamless copper or copper alloy excepting those which pass through oil storage tanks. Oil pipes within the engine and boiler spaces are to be fitted where they can be readily inspected and repaired, and after jointing they are to be tested to 3,5 kg/cm^2 (50 lb/in^2), or twice the maximum working pressure, whichever is the greater.

Valves and Cocks

313 The valves, cocks and their pipe connections are to be so arranged that oil cannot be admitted into tanks which are not structurally suitable for the carriage of oil or into tanks which can be used for the carriage of fresh water intended for boiler feed or for drinking.

In passenger ships provision is to be made for the transfer of oil fuel from any oil fuel storage or settling tank to any other oil fuel storage or settling tank in the event of fire or damage.

314 Every oil fuel suction pipe from a double bottom tank is to be fitted with a valve or cock.

315 Every oil fuel suction pipe from a storage, settling and daily service tank situated above the double bottom and every oil fuel levelling pipe within the boiler room or engine room is to be fitted with a valve or cock secured to the tank. In the case of fore peak tanks, these valves are to be fitted on the tank side of the bulkhead.

In the engine and boiler spaces, such valves and cocks are to be capable of being closed locally and from positions which will always be accessible in the event of fire taking place in these spaces. Instructions for closing the valves or cocks are to be indicated at the valves and cocks and at the remote control positions.

In the case of very small tanks consideration will be given to the omission of remote controls.

316 Every oil fuel suction pipe which is led into the engine and boiler spaces from a tank situated above the double bottom outside these spaces is to be fitted in the machinery space with a remote controlled valve, except where the valve on the tank is already remote controlled.

317 All valves and cocks forming part of the oil fuel installation are to be capable of being controlled from readily accessible positions which, in the engine and boiler spaces, are to be above the working platform.

Valves or cocks are to be interposed between the pumps and the suction and discharge pipes, in order that any pump may be shut off for opening up and overhauling.

Oil fuel valves are to be so constructed as to prevent the possibility of any cover being slacked back or loosened when operating the valves. The valves and cocks are to be fitted with legible nameplates.

318 Where the filling pipes to deep oil tanks are not connected to the tanks near the top, they are to be provided with non-return valves at the tanks or with valves or cocks fitted and controlled as in the case of the outlet valves or cocks on these tanks.

319 Open drains for removing the water from oil tanks are to be fitted with valves or cocks of self-closing type and suitable provision is to be made for collecting the oily discharge.

Oil Fired Galleys

320 The fuel oil tank is to be located outside the galley and is to be fitted with approved means of filling and venting. The fuel supply to the burners is to be controlled from a position which will always be accessible in the event of a fire occuring in the galley. The galley is to be well ventilated.

When liquefied petroleum gas is used similar provisions are to be made.

Filling Arrangements

321 In passenger ships, the filling station is to be isolated from other spaces and is to be efficiently drained

and ventilated. Provision is to be made against over-pressure in the filling pipe lines and any relief valve fitted for this purpose is to discharge to an overflow tank or other safe position.

Alternative Carriage of Oil Fuel and Water Ballast

322 Where it is intended to carry oil fuel and water ballast in the same compartments alternatively, the valves or cocks connecting the suction pipes of these compartments with the ballast pump and those connecting them with the oil fuel transfer pump are to be so arranged that the oil may be pumped from any one compartment by the oil fuel pump at the same time as the ballast pump is being used on any other compartment.

Where settling or service tanks are fitted each having a capacity sufficient to permit of 12 hours normal service without replenishment, the above requirement may be dispensed with.

323 Attention is drawn to the statutory regulations issued by National Authorities in connection with the International Convention for Prevention of Pollution of the Sea by Oil, 1954.

Deep tanks for the Alternative Carriage of Oil, Water Ballast or Dry Cargo

324 In the case of deep tanks which can be used for the carriage of oil fuel, cargo oil, water ballast or dry cargo, provision is to be made for blank flanging the oil and water ballast filling and suction pipes, also the steam heating coils if retained in place, when the tank is used for dry cargo and for blank flanging the bilge suction pipes when the tanks are used for oil or water ballast.

If the deep tanks are connected to an overflow system the arrangements are to be such that liquid or vapour from other tanks cannot enter the deep tanks when dry cargo is carried in them.

Oily Bilge Drainage and Sediment Suctions

325 Provision is to be made for the drainage of oil gutterways, oil wells and cofferdams. (*See* D 1926 to D 1929, quoted at end of this Section.)

Fresh Water Piping

326 Pipes in connection with compartments used for storing boiler feed water are to be separate and distinct from any pipes which may be used for oil or oily water, and are not to be led through tanks which contain oil, nor are oil pipes to be led through boiler feed water tanks.

Similar precautions are necessary when the connections are such that fresh water carried in other tanks can be used as reserve feed water.

Service, Settling and other Oil Fuel Tanks

327 In general, the minimum thickness of the plating of these tanks, when they do not form part of the structure of the ship, is to be 5 mm (0·19 in), but in the case of very small tanks, the minimum thickness may be 3 mm (0·125 in).

For rectangular steel tanks of welded construction the plate thicknesses are to be not less than indicated in Table E 3.1. The stiffeners are to be of approved dimensions.

TABLE E 3.1

Thickness of Plate in mm (inches)	Head from Bottom of Tank to Top of Overflow Pipe in metres (feet)				
	2,5 (8)	3,0 (10)	3,7 (12)	4,3 (14)	4,9 (16)
	Breadth of Panel in mm (inches)				
5 (0·19)	585 (22)	525 (20)			
6 (0·22)	725 (26)	645 (23)	590 (21)		
7 (0·25)	860 (30)	770 (27)	700 (25)	650 (23)	
8 (0·31)	1000 (39)	900 (35)	820 (32)	750 (30)	700 (28)
10 (0·375)	1280 (48)	1140 (43)	1040 (39)	960 (36)	900 (34)

The dimension given in Table E 3.1 for the breadth of the panel is the maximum distance allowable between continuous lines of support, which may be stiffeners, wash-plates or the boundary plating of the tank.

Where necessary, stiffeners are to be provided and if the length of the stiffener exceeds twice the breadth of the panel, transverse stiffeners are also to be fitted, or, alternatively, tie bars are to be provided between stiffeners on opposite sides of the tank.

On completion the tanks are to be tested by a head of water equal to the maximum to which the tanks may be subjected but not less than 2,5 m (8 ft) above the crown of the tank.

Tanks in which the oil fuel is heated are to be provided with a suitable thermometer pocket.

Water Drainage from Settling Tanks

328 Settling tanks are to be provided with means for draining water from the bottom of the tanks.

If settling tanks are not provided, the oil fuel bunkers or daily service tanks are to be fitted with water drains (*see* 319).

Ventilation

329 The spaces in which the oil fuel burning appliances, and the oil fuel settling and service tanks are fitted, are to be well ventilated and easy of access.

Boiler Insulation and Air Circulation in Boiler Room

330 The boilers are to be suitably lagged. The clearance spaces between the boilers and tops of the double bottom tanks and between the boilers and the sides of the storage tanks in which oil fuel or cargo oil is carried, are to be adequate for the free circulation of air necessary to keep the temperature of the stored oil well below its flash point.

331 Where water tube boilers are installed, there should be a space of at least 760 mm (2·5 ft) between the tank top and the underside of the pans forming the bottom of the combustion spaces.

332 Smoke-box doors are to be shielded and well fitting, and the uptake joints made airtight.

Funnel Dampers

333 Dampers which are capable of completely closing the gas passages are not to be fitted to inner funnels of ships equipped for burning oil fuel only. In ships burning oil or coal alternatively, dampers may be retained if they are provided with a suitable device whereby they may be securely locked in the fully open position.

Steam Heating Arrangements

334 Where steam is used for heating oil fuel, cargo oil or lubricating oil, either in bunkers, tanks, heaters or separators, the exhaust drains are to discharge the condensate into an observation tank in a well lighted and accessible position where it can be readily seen whether or not it is free from oil (*see* E 1118).

335 The steam heating pipes in contact with oil are to be of iron, steel, approved aluminium alloy or approved copper alloy and are to be tested, after being fitted on board, to twice the maximum pressure to which they can be subjected.

336 The thickness of steel steam heating pipes is to be determined from the formulæ in E 512 and E 513.

Control of Pumps

337 The power supply to the oil fuel transfer and pressure pumps and to the cargo oil pumps is to be capable of being stopped from a position which will always be accessible in the event of fire taking place in the compartment in which they are situated, as well as from the compartment itself.

Precautions against Fire

338 Settling and daily service oil fuel tanks and oil fuel filters are not to be situated immediately above boilers or other highly heated surfaces.

339 Oil fuel pressure pipes are to be led, wherever practicable, remote from heated surfaces and electrical appliances, but where this is impracticable, the pipes are to have a minimum number of joints and are to be led in well lighted and readily visible positions.

340 The arrangement and location of short sounding pipes to oil tanks are to be in accordance with E 413. (For alternative sounding arrangements, *see* E 414.)

341 Water service pipes and hoses are to be fitted in order that the floor plates and tank top or shell plating in way of boilers, oil fuel apparatus or deep storage tanks in the engine and boiler spaces can at any time be flushed with sea water.

342 So far as is practicable the use of wood is to be avoided in the engine rooms, boiler rooms and tunnels of ships burning oil fuel.

343 Drip trays are to be fitted at the furnace mouths to intercept oil escaping from the burners and under all other oil fuel appliances which require to be opened up frequently for cleaning or adjustment. The arrangements are to be such that a burner cannot be withdrawn unless the oil fuel supply to that burner is shut off and that the oil cannot be turned on unless the burner has been correctly coupled to the supply line.

For alternately fired furnaces of boilers using exhaust gases and oil fuel, the exhaust gas inlet pipe is to be provided with an isolating device and interlocking arrangements whereby oil fuel can only be supplied to the burners when the isolating device is closed to the boiler.

Separation of Cargo Oils from Oil Fuel

344 Pipes conveying vegetable oils or similar cargo oils are not to be led through oil fuel tanks, nor are oil fuel pipes to be led through tanks containing these cargo oils. (*See* D 1931, quoted at end of this Section.)

Oil Drainage in way of Refrigerated Cargo Chambers

345 The insulation of all oil storage tank tops is to have an air space of 50 mm (2 in) provided between the underside of the insulation and the tank top plating and the

supporting battens are to be arranged to provide free drainage to the bilges. Alternatively, either 12,5 mm (0·5 in) thick inodorous material, or successive coatings of approved oil resisting compositions to a total thickness of about 5 mm (0·19 in) may be applied to the tank top plating.

346 Riveted bulkheads of deep tanks intended for the carriage of oil are to be separated from refrigerated compartments by a cofferdam.

Provision is to be made for ventilating the cofferdam, the vents being led to the open air and their outlets being fitted with a wire gauze diaphragm which can be easily removed for renewal.

Where the tank bulkhead is wholly welded, including its boundary connections, the cofferdam may be omitted, provided successive coatings of an approved oil impervious composition be applied to the refrigerated compartment side of the tank bulkhead. The total thickness of the coating required will depend on the composition used and the method of application.

Extracts from Chapter D for reference

Protection and Drainage in Tanks Carrying Oil Fuel or Lubricating Oil

D 1926 Compartments carrying oil fuel or lubricating oil are to be separated by cofferdams from those carrying fresh or feed water. Oil fuel or lubricating oil compartments are to be similarly separated from those carrying vegetable oil. Cofferdams are to be suitably ventilated.

For tanks carrying vegetable and similar oils, *see* 1931.

D 1927 Gutterways are to be arranged at the foot of bulkheads in boiler rooms to ensure that leakage shall have free drainage to the wells or limbers.

D 1928 Drip trays or gutterways with suitable draining arrangements are to be provided for all tanks which do not form part of the hull structure, at pumps, valves and elsewhere where there is a possibility of leakage. Drip trays are also to be fitted under oiltight decks, except if these are completely welded, when the drip trays need only be fitted over the boilers.

D 1929 If cargo is carried in a compartment adjacent to an oil fuel settling tank which may be heated, the compartment side of the bulkhead or deck is to be insulated or equivalent arrangements provided.

Tanks carrying Vegetable and Similar Oils

D 1931 Deep or peak tanks carrying vegetable or similar oils are to be separated from those carrying oil fuel, lubricating oil or fresh or feed water by a cofferdam.

Cofferdams are not required between oil fuel double bottom tanks and deep tanks above provided the inner bottom plating is not subjected to a head of oil fuel.

Section 4

AIR, OVERFLOW AND SOUNDING PIPES

Air and Overflow Pipes

401 Air pipes are to be fitted at the opposite end of the tank to that at which the filling pipes are placed and/or at the highest part of the tank.

Where the tank top is of unusual or irregular profile special consideration will be given to the number and position of the air pipes.

Nameplates are to be affixed to the upper ends of all air pipes.

402 Air pipes to double bottom tanks, deep tanks extending to the shell plating or tanks which can be run up from the sea are to be led to above the bulkhead deck.

Air pipes to oil fuel and cargo oil tanks, cofferdams and all tanks which can be pumped up are to be led to the open. (For height of air pipes above deck, *see* D 2911, quoted at end of this Section.)

403 The open ends of air pipes to oil fuel and cargo oil tanks are to be situated where no danger will be incurred from issuing oil or vapour when the tank is being filled and each opening is to be furnished with a wire gauze diaphragm of incorrodible material which can be readily removed for cleaning or renewal.

404 Air pipes from lubricating oil storage tanks may terminate in the machinery space, provided the open ends are so situated that issuing oil cannot come into contact with electrical equipment or heated surfaces.

405 The closing appliances fitted to tank air pipes, in accordance with D 2912, are to be of a type which will prevent excessive pressure coming on the tanks.

Provision is to be made for relieving vacuum when the tanks are being pumped out and for this purpose a hole about 10 mm (0·375 in) in diameter in the bend of the air pipe or in a suitable position in the closing device will be acceptable.

406 In the case of all tanks which can be pumped up, either by the ship's pumps or by shore pumps through a filling main, the total cross-sectional area of the air pipes to

each tank or of the overflow pipes where an overflow system is provided, is not to be less than 25 per cent greater than the effective area of the respective filling pipes.

Where tanks are fitted with cross flooding connections the air pipes are to be of adequate area for these connections. Wood plugs and other devices which can be secured closed are not to be fitted at the outlets.

In wire gauze diaphragms at air pipe openings, the area of the clear opening is not to be less than the cross-sectional area required for the pipe.

Air pipes are not to be less than 50 mm (2 in) bore.

407 The arrangement of the overflow system is to be such that in the event of any one of the tanks being bilged, tanks situated in other watertight compartments of the ship cannot be flooded from the sea through the overflow main.

Air and overflow pipes are to be arranged to be self-draining under normal conditions of trim.

408 Overflow pipes are to be fitted to oil fuel storage, settling and daily service tanks when the pressure head corresponding to the height of the air pipe is greater than that for which the tanks are suitable or when the sectional area of the air pipe is less than required by 406.

The pipe is to be led to an overflow tank of adequate capacity or to a storage tank having a space reserved for overflow purposes.

A sight glass is to be provided in the overflow pipe to indicate when the tanks are overflowing or, alternatively, an alarm device is to be provided to give warning either when the tanks are overflowing or when the oil reaches a predetermined level in the tanks.

409 Where overflows from tanks which are used for the alternative carriage of oil and water ballast are connected to an overflow system, arrangements are to be made to prevent water ballast overflowing into tanks containing oil (*see also* E 324).

410 Air and overflow pipes are to be of steel having a minimum thickness of 5 mm (0·19 in) or other approved material and thickness. Steel pipes slightly less in thickness may be accepted, provided they be suitably coated to prevent corrosion. Where not in contact with oil fuel or cargo oil, suitable protection may be provided by galvanising the pipes on completion.

The portions of air and overflow pipes fitted above deck are to be of steel or other approved ductile material and of robust construction.

Where flanged connections are employed, heavy flanges with closely spaced bolts are to be fitted.

Sounding Pipes

411 Provision is to be made for sounding all tanks, and the bilges of those compartments which are not at all times readily accessible.

The soundings are to be taken as near the suction pipes as practicable.

412 Sounding pipes, including those for the double bottom tanks below the machinery spaces, should be led to positions above the bulkhead deck which are at all times accessible.

These pipes should be as straight as practicable, and if curved to suit the structure of the ship, the curvature must be sufficiently easy to permit the ready passage of the sounding rod or chain.

Nameplates are to be affixed to the upper ends of all sounding pipes.

413 In machinery spaces and tunnels where it is not always practicable to extend the sounding pipes as mentioned in 412, short sounding pipes extending to readily accessible positions above the platform may be fitted.

Short sounding pipes to oil fuel and lubricating oil tanks are to be fitted with cocks having parallel plugs with permanently attached handles so loaded that, on being released, they automatically close the cocks. As a further precaution against fire, such sounding pipes are to be located in positions as far removed as possible from any heated surface or electrical equipment and, where necessary, effective shielding is to be provided in way of such surfaces and/or equipment.

Short sounding pipes to tanks other than oil tanks are to be fitted with shut-off cocks or with screw caps attached to the pipes by chains.

In passenger ships, short sounding pipes are permissible only for sounding cofferdams and double bottom tanks situated in the machinery space and are in all cases to be fitted with self-closing cocks as described in the foregoing.

414 Tank sounding devices of approved type may be used in lieu of sounding pipes. These devices are to be tested, after fitting on board, to the satisfaction of the Surveyors.

415 If gauge glasses are used for indicating the level of liquid in tanks containing lubricating oil, oil fuel or other inflammable liquid, the glasses are to be of heat-resisting quality adequately protected from mechanical damage and fitted with self-closing valves at the lower ends and at the top ends if these are connected to the tanks below the maximum liquid level.

416 Sounding pipes to oil compartments are not to terminate within refrigerated cargo chambers or in the fan and battery rooms for these chambers, nor are these pipes to terminate in enclosed spaces from which access is provided to refrigerated cargo chambers or their fan and battery rooms, if it be practicable to avoid doing so.

Where these sounding pipes do terminate in such spaces they are to be fitted with self-closing cocks having parallel plugs.

417 Sounding pipes are not to be less than 32 mm (1·25 in) bore. All sounding pipes, whether for compartments or tanks, which pass through refrigerated spaces or the insulation thereof, in which the temperatures contemplated are 0°C (32°F) or below, are not to be less than 65 mm (2·5 in) bore.

418 All pipes, including scupper pipes, air pipes and sounding pipes which pass through chambers intended for the carriage or storage of refrigerated produce are to be well insulated.

Where such pipes pass through chambers intended for a temperature of 0°C (32°F) or below, they are also to be insulated from the steel structure except in positions where the temperature of the structure is mainly controlled by the external temperature and will normally be above freezing point. Pipes passing through a deck plate within the ship side insulation, where the deck is fully insulated below and has an insulation ribband on top, are to be attached to the deck plating.

In the case of pipes adjacent to the shell plating, metallic contact between the pipes and the shell plating or frames is to be arranged as far as practicable.

The air refreshing pipes to and from refrigerated compartments need not, however, be insulated from the steel work.

419 Sounding pipes are to be of steel having a minimum thickness of 4,5 mm (0·17 in) or other approved material and thickness. Steel pipes slightly less in thickness may be accepted, provided they be suitably coated to prevent corrosion. Where not in contact with oil fuel or cargo oil, suitable protection may be provided by galvanising the pipes on completion.

Where flanged connections are employed, heavy flanges with closely spaced bolts are to be fitted.

420 Striking plates of adequate thickness and size are to be fitted under open ended sounding pipes.

Where slotted sounding pipes having closed ends are employed, the closing plugs are to be of substantial construction.

421 Elbow sounding pipes are not to be used for deep tanks unless the elbows and pipes are situated within closed cofferdams or within tanks containing similar liquids.

They may, however, be fitted to other tanks and may be used for sounding bilges, provided it is not practicable to lead them direct to the tanks or compartments.

The elbows are to be of heavy construction and adequately supported.

In passenger ships, elbow sounding pipes are not permissible.

Extract from Chapter D for reference

Air and Sounding Pipes

D 2911 The height of air pipes from the upper surface of decks exposed to the weather, to the point where water may have access below is not normally to be less than:—

On the freeboard deck ... 760 mm (30 in),
On superstructure decks ... 450 mm (17·5 in).

These heights are to be measured above sheathing, where fitted.

Lower heights may be approved in cases where these are essential for the working of the ship, provided the design and arrangements are otherwise satisfactory.

D 2912 All openings of air and sounding pipes are to be provided with permanently attached satisfactory means of closing to prevent the free entry of water.

D 2913 Striking plates of suitable thickness, or their equivalent, are to be fitted under all sounding pipes.

D 2914 Air and sounding pipes are to be well protected in all spaces. This protection is to be of steel in bulk cargo spaces or their equivalent, and also in areas where contact with large containers, fork lift trucks or similar items is a possibility.

Section 5

PRESSURE PIPES

General

501 The requirements of this Section, unless otherwise specifically stated, are primarily intended for piping systems in which the design pressure is 7 kg/cm² (100 lb/in²) and over.

Copper and Copper Alloy Pipes

502 Copper and copper alloy pipes are to be seamless or of approved welded type.

Branches are to be provided by cast or stamped fittings, by pipe pressings, or by other approved fabrications.

503 Brazing and welding materials are to be suitable for the operating temperature and for the medium being carried. All brazing and welding is to be carried out to the satisfaction of the Surveyors.

504 The maximum working temperatures permitted for pipe and branch materials are indicated in Table E 5.1. Where it is proposed to use other copper alloys, particulars of chemical composition and mechanical properties at the working temperature including, if applicable, creep and rupture data, are to be submitted for consideration.

505 Where copper and copper alloy pipes are bent, they are to be made 10 per cent thicker than required by 506 to provide for thinning at the bend.

In no case is the radius of curvature at the centre line of the pipe to be less than twice the outside diameter of the pipe.

506 The minimum thickness of seamless copper and copper alloy pipes is to be determined by the following formula:—

$$T = \frac{PD}{2f} + 0{,}75 \text{ mm} \left(T = \frac{PD}{2f} + 0{\cdot}03 \text{ in}\right)$$

where T = thickness, in mm (in),

P = design pressure, in kg/cm^2 (lb/in^2), which in the case of feed pipes, is to be 1,25 times the boiler design pressure,

D = outside diameter, in mm (in),

f = allowable stress, in kg/cm^2 (lb/in^2), from Table E 5.1. Intermediate values of stresses to be obtained by linear interpolation.

507 Pipes which have been hardened by cold bending are to be suitably heat treated on completion of fabrication and prior to testing by hydraulic pressure. Copper pipes are to be annealed and copper alloy pipes are to be either annealed or stress relief heat treated.

Steel Pipes

508 Steel pipes for a design pressure exceeding 17,5 kg/cm^2 (250 lb/in^2) or a temperature exceeding 220°C (428°F), and all feed pipes and pressure pipes conveying heated oil are to be manufactured and tested in accordance with the requirements of Q 7. Where it is proposed to use materials for pipes other than shown in Q 7, the information called for in 511 (a) is to be submitted for consideration.

509 Pipes other than those mentioned in 508 may be made and tested

(a) to the requirements of Q 7, or,

(b) in accordance with an approved national specification, except that forge butt welded pipes are not acceptable.

510 Pipes having forge butt welded longitudinal seams are not to be used for oil fuel systems, for heating coils in oil tanks, or for pressures exceeding 3,5 kg/cm^2 (50 lb/in^2).

511 The thickness of steel pipes intended for steam, feed, air, oil fuel and other pressure services is to be determined by the formulæ in 512 and 513 and the following definitions are given in respect of the symbols used in the formulæ:—

(a) The allowable stress, f, is obtained from the material properties of the appropriate category, grade and tensile range of steel indicated in Q 7 and is to be taken as the lowest of the following values:—

$$f = \frac{E_t}{1{,}6} \qquad f = \frac{R_{20}}{2{,}7} \qquad f = \frac{S_R}{1{,}6}$$

where E_t = specified minimum lower yield stress or 0,2 per cent proof stress at the temperature under consideration,

R_{20} = specified minimum tensile strength at room temperature,

S_R = average stress to produce rupture in 100 000 hours at the temperature under consideration.

In general, when determining the value of the allowable stress, f, the temperature of the pipeline is to be taken as the maximum temperature of the internal fluid, but in no case is to be less than 100°C (212°F). In the case of pipes for superheated steam the temperature is to be taken as the designed operating steam temperature for the pipeline provided the temperature at the superheater outlet is closely controlled. Where temperature fluctuations exceeding 14 degC (25 degF) above the designed temperature are to be expected in normal service the steam temperature to be used for determining the allowable stress is to be increased by the amount of this excess.

Values of the allowable stress, f, are shown in Tables E 5.2 and E 5.3. For intermediate temperatures, values of the allowable stress may be obtained by interpolation.

Where it is proposed to use, for high temperature service, alloy steels other than those stated in Q 7, particulars of the tube sizes, design conditions and appropriate national or proprietary material specifications are to be submitted for consideration.

Where the material does not conform to an established standard, particulars of the chemical composition, deoxidising medium, heat treatment, mechanical properties and

TABLE E 5.1

Pipe Material	Minimum tensile strength kg/mm²	0,5 per cent proof stress kg/mm²	Allowable Stress kg/cm²										
			50°C	75°C	100°C	125°C	150°C	175°C	200°C	225°C	250°C	275°C	300°C
Copper	22	6	420	415	405	390	330	270	220				
Aluminium Brass	33	13	705	700	685	665	635	435	245				
Copper Nickel 95/5 & 90/10	28	14	705	700	685	665	645	610	570	510	445	385	
Copper Nickel 70/30	40	14	845	820	775	740	700	675	650	625	600	575	550

or in British units:—

Pipe Material	Minimum tensile strength ton/in²	0·5 per cent proof stress ton/in²	Allowable Stress lb/in²										
			50°C	75°C	100°C	125°C	150°C	175°C	200°C	225°C	250°C	275°C	300°C
Copper	14	4	5970	5910	5760	5550	4690	3840	3130				
Aluminium Brass	21	8	10 030	9960	9740	9460	9040	6190	3490				
Copper Nickel 95/5 & 90/10	18	9	10 030	9960	9740	9460	9180	8680	8110	7260	6340	5480	
Copper Nickel 70/30	25·5	9	12 030	11 680	11 030	10 530	9960	9600	9250	8890	8540	8180	7820

measured or estimated long-term stress to rupture data at the proposed operating temperature are to be submitted for the purpose of assessing a safe allowable stress.

(b) (i) The design pressure, P, for feed pipes is to be taken as 1,25 times the design pressure of the boiler, or the maximum pressure which can be developed in the feed line in normal service, whichever is the greater.

(ii) With water tube boiler installations the design pressure, P, is to be taken as the approved design pressure of the boiler for steam pipes between the boiler and integral superheater and as the pressure to which the superheater safety valves are set for the steam pipes leading from the superheater. Where the superheater safety valves are controlled by pilot valves operated from the saturated steam drum, then the design pressure for the steam pipes leading from the superheater is to be taken as the design pressure of the boiler.

NOTE:—In installations where the boiler pressure, as controlled by the safety valve settings, is less than the design pressure of the boiler, it will be permissible for thicknesses of external steam and feed pipes to be based on the former.

(c) The thickness, T, determined by the formula in 512 is the minimum thickness for straight pipes and the thickness, T_b, determined by the formulæ in 513 is the minimum thickness of a straight pipe from which a pipe bend is to be made. In both cases provision must be made for any minus tolerance to which the pipes may be manufactured.

(d) The outside diameter, D, of the pipe may be subject to manufacturing tolerances but these tolerances are not to be used in the evaluation of formulæ.

512 The minimum thickness of straight steel pipes intended for the services referred to in 511 is to be determined by the following formula:—

$$T = \frac{CPD}{2f + P}$$

where T = minimum thickness, in mm (in). (*See* NOTES 1 and 2),

P = design pressure, in kg/cm² (lb/in²),

D = outside diameter of pipe, in mm (in),

f = allowable stress, in kg/cm² (lb/in²), from Tables E 5.2 or E 5.3, the symbols being as defined in 511,

C = 1,4 for oil fuel pipes and steam heating pipes in contact with oil,

= 1,0 for all other pipes.

For pipes intended for the services permitted by 509 and made and tested in accordance with 509 (b) the allowable stress is to be taken as 80 per cent of the values given in Table E 5.3 for the appropriate specified minimum tensile strength.

The formula does not provide for adverse corrosion conditions. In the case of steam and feed pipes over 25 mm (1 in) bore intended for low pressure boilers having design pressures up to 17,5 kg/cm² (250 lb/in²), and for any boilers with open feed systems, these pipes are to be made 1 mm (0·04 in) thicker than required by the formula.

NOTES:—

1. The value of T is the minimum thickness for straight pipes and provision must be made for any minus tolerance to which the pipes may be manufactured. (*See* Q 707 (c) for tolerance on wall thickness.)

2. Practical considerations such as manufacture, fabrication and robustness may make it necessary for pipes thicker than this minimum to be used. In such cases, the nominal pipe thickness should in general, not be less than shown in Table E 5.4 for the appropriate standard pipe size.

513 The minimum thickness, T_b, of a straight steel pipe to be used for a pipe bent to a radius in accordance with Table E 5.5 is to be determined by the formulæ below, except where it can be demonstrated that the use of a thickness less than T_b would not reduce the thickness below T at any point after bending. (*See* Notes 1 and 2.)

(i) For pipes bent to the radii specified in Table E 5.5 Columns 2 and 4:—

$$T_b = 1{,}125\ T \qquad (1)$$

(ii) For pipes exceeding 220 mm (8·625 in) outside diameter, and where T is 32 mm (1·25 in) or more, bent to the radii specified in Table E 5.5 Column 5:—

$$T_b = 1{,}1\ T \qquad (2)$$

NOTES:—

1. The value of T_b is the minimum thickness and provision must be made for any minus tolerance to which the pipes may be manufactured. (*See* Q 707 (c) for tolerance on wall thickness.)

2. Practical considerations such as manufacture, fabrication and robustness may make it necessary for pipes thicker than this minimum to be used. In such cases, the nominal thickness of a straight steel pipe to be used for a pipe bend should in general, not be less than shown in Table E 5.4.

TABLE E 5.2 –

Grade of Steel	Yield Stress kg/mm²	Tensile Strength kg/mm²	Allowable Stress kg/cm² (*see* E 511) 100°C	150°C	200°C	250°C	300°C	350°C	390°C	400°C	410°C	420°C	430°C	440°C	450°C	460°C
Carbon	21,3	35–47	1165	1150	1125	1060	930	825	765	750	670	590	520	455	405	350
Carbon	25,2	42–54	1280	1260	1210	1140	1005	915	885	780	670	590	520	455	405	350
1 Cr–½ Mo	23,6	42–63	1420	1375	1325	1190	1045	945	930	930	925	920	915	910	905	900
2¼ Cr–1 Mo (NOTE 1)	23,6	42–57	1245	1135	975	945	915	875	850	845	840	835	830	825	825	825
2¼ Cr–1 Mo (NOTE 2)	26,8	50–70	1610	1595	1560	1490	1440	1375	1320	1305	1290	1280	1270	1260	1250	1240
½ Cr–½ Mo–¼ V	30,0	47–62	1610	1595	1560	1490	1440	1375	1320	1305	1290	1280	1270	1260	1250	1240

or in British units:—

Grade of Steel	Yield Stress ton/in²	Tensile Strength ton/in²	Allowable Stress lb/in² (*see* E 511) 100°C	150°C	200°C	250°C	300°C	350°C	390°C	400°C	410°C	420°C	430°C	440°C	450°C	460°C
Carbon	13·5	22·2–29·8	16 580	16 370	16 000	15 090	13 220	11 730	10 890	10 680	9540	8390	7400	6470	5760	4980
Carbon	16·0	26·7–34·3	18 210	17 920	17 210	16 210	14 300	13 020	12 600	11 100	9540	8390	7400	6470	5760	4980
1 Cr–½ Mo	15·0	26·7–40·0	20 200	19 560	18 850	16 920	14 870	13 440	13 220	13 220	13 170	13 090	13 010	12 970	12 880	12 800
2¼ Cr–1 Mo (NOTE 1)	15·0	26·7–36·2	17 710	16 150	13 880	13 440	13 020	12 450	12 090	12 020	11 950	11 880	11 800	11 730	11 730	11 730
2¼ Cr–1 Mo (NOTE 2)	17·0	31·7–44·4	22 900	22 680	22 200	21 200	20 480	19 560	18 790	18 580	18 360	18 210	18 080	17 920	17 790	17 640
½ Cr–½ Mo–¼ V	19·0	29·8–39·4	22 900	22 680	22 200	21 200	20 480	19 560	18 790	18 580	18 360	18 210	18 080	17 920	17 790	17 640

NOTES: 1. Annealed condition.
2. Normalised and tempered condition.

CATEGORY I MATERIAL

Allowable Stress kg/cm² (*see* E 511)														Tensile Strength kg/mm²	Yield Stress kg/mm²	Grade of Steel
470°C	480°C	490°C	500°C	510°C	520°C	530°C	540°C	550°C	560°C	570°C	580°C	590°C	600°C			
310	275													35–47	21,3	Carbon
310	275													42–54	25,2	Carbon
895	895	890	885	775	635	500	395	310	255	205				42–63	23,6	1 Cr–$\frac{1}{2}$ Mo
820	815	810	800	795	785	720	620	530	455	385	325	275	240	42–57	23,6	2$\frac{1}{4}$ Cr–1 Mo (NOTE 1)
1230	1215	1200	1070	945	825	720	620	530	455	385	325	275	240	50–70	26,8	2$\frac{1}{4}$ Cr–1 Mo (NOTE 2)
1230	1215	1200	1180	1035	885	755	635	550	460	405	345			47–62	30,0	$\frac{1}{2}$ Cr–$\frac{1}{2}$ Mo–$\frac{1}{4}$ V

Allowable Stress lb/in² (*see* E 511)														Tensile Strength ton/in²	Yield Stress ton/in²	Grade of Steel
470°C	480°C	490°C	500°C	510°C	520°C	530°C	540°C	550°C	560°C	570°C	580°C	590°C	600°C			
4410	3910													22·2–29·8	13·5	Carbon
4410	3910													26·7–34·3	16·0	Carbon
12 730	12 730	12 660	12 590	11 030	9040	7110	5620	4410	3630	2920				26·7–40·0	15·0	1 Cr–$\frac{1}{2}$ Mo
11 670	11 600	11 510	11 390	11 310	11 170	10 240	8820	7540	6470	5480	4620	3910	3420	26·7–36·2	15·0	2$\frac{1}{4}$ Cr–1 Mo (NOTE 1)
17 500	17 290	17 080	15 250	13 440	11 730	10 240	8820	7540	6470	5480	4620	3910	3420	31·7–44·4	17·0	2$\frac{1}{4}$ Cr–1 Mo (NOTE 2)
17 500	17 290	17 080	16 790	14 720	12 600	10 740	9040	7830	6550	5760	4910			29·8–39·4	19·0	$\frac{1}{2}$ Cr–$\frac{1}{2}$ Mo–$\frac{1}{4}$ V

NOTES: 1. Annealed condition.

2. Normalised and tempered condition.

TABLE E 5.3 —

Grade of Steel	Yield Stress kg/mm²	Tensile Strength kg/mm²	Allowable Stress kg/cm² (*see* E 511)												
			100°C	150°C	200°C	250°C	300°C	350°C	400°C	410°C	420°C	430°C	440°C	450°C	460°C
Carbon	16,5	33–45	785	755	730	665	575	455	450	445	445	445	445	405	350
Carbon	17,8	35–47	850	830	815	730	635	525	515	515	515	515	455	405	350
Carbon	21,5	42–54	1125	1100	1080	990	885	785	770	670	590	520	455	405	350
1 Cr–½ Mo	22,5	42–63	1215	1170	1130	1010	885	800	785	785	780	775	775	770	765
2¼ Cr–1 Mo (NOTE 1)	21,5	42–57	1060	960	830	800	775	740	720	715	715	710	705	700	695
2¼ Cr–1 Mo (NOTE 2)	25,0	50–70	1365	1355	1330	1270	1215	1170	1105	1100	1090	1080	1070	1060	1055
½ Cr–½ Mo–¼ V	28,0	47–62	1365	1355	1330	1270	1215	1170	1105	1100	1090	1080	1070	1060	1055

or in British units :— **TABLE E 5.3 —**

Grade of Steel	Yield Stress ton/in²	Tensile Strength ton/in²	Allowable Stress lb/in² (*see* E 511)												
			100°C	150°C	200°C	250°C	300°C	350°C	400°C	410°C	420°C	430°C	440°C	450°C	460°C
Carbon	10·5	21·0–28·6	11 170	10 740	10 380	9460	8190	6470	6400	6340	6340	6340	6340	5760	4980
Carbon	11·3	22·2–29·6	12 090	11 810	11 590	10 380	9040	7460	7330	7330	7330	7330	6470	5760	4980
Carbon	13·7	26·7–34·3	16 000	15 650	15 370	14 090	12 600	11 170	10 950	9540	8390	7400	6470	5760	4980
1 Cr–½ Mo	14·3	26·7–40·0	17 290	16 630	16 080	14 380	12 600	11 380	11 170	11 170	11 100	11 020	11 020	10 950	10 890
2¼ Cr–1 Mo (NOTE 1)	13·7	26·7–36·2	15 080	13 670	11 810	11 380	11 020	10 530	10 240	10 180	10 180	10 100	10 030	9960	9890
2¼ Cr–1 Mo (NOTE 2)	15·9	31·7–44·4	19 410	19 280	18 920	18 070	17 280	16 640	15 710	15 660	15 500	15 370	15 220	15 080	15 010
½ Cr–½ Mo–¼V	17·8	29·8–39·4	19 410	19 280	18 920	18 070	17 280	16 640	15 710	15 660	15 500	15 370	15 220	15 080	15 010

NOTES: 1. Annealed condition. 2. Normalised and tempered condition.

CATEGORY II MATERIAL

Allowable Stress kg/cm² (see E 511)														Tensile Strength kg/mm²	Yield Stress kg/mm²	Grade of Steel
470°C	480°C	490°C	500°C	510°C	520°C	530°C	540°C	550°C	560°C	570°C	580°C	590°C	600°C			
310	275													33–45	16,5	Carbon
310	275													35–47	17,8	Carbon
310	275	240	205											42–54	21,5	Carbon
760	760	755	755	750	635	500	395	310	255	205				42–63	22,5	1 Cr–½ Mo
690	690	685	680	680	675	665	620	530	455	385	325	275	240	42–57	21,5	2¼ Cr–1 Mo (Note 1)
1045	1035	1020	1005	945	825	720	620	530	455	385	325	275	240	50–70	25,0	2¼ Cr–1 Mo (Note 2)
1045	1035	1020	1005	990	885	755	635	550	460	405	345			47–62	28,0	½ Cr–½ Mo–¼ V

CATEGORY II MATERIAL

Allowable Stress lb/in² (see E 511)														Tensile Strength ton/in²	Yield Stress ton/in²	Grade of Steel
470°C	480°C	490°C	500°C	510°C	520°C	530°C	540°C	550°C	560°C	570°C	580°C	590°C	600°C			
4410	3910													21·0–28·6	10·5	Carbon
4410	3910													22·2–29·6	11·3	Carbon
4410	3910	3420	2920											26·7–34·3	13·7	Carbon
10 810	10 810	10 740	10 740	10 680	9040	7110	5620	4410	3630	2920				26·7–40·0	14·3	1 Cr–½ Mo
9810	9810	9750	9670	9670	9600	9460	8820	7540	6470	5480	4620	3910	3420	26·7–36·2	13·7	2¼ Cr–1 Mo (Note 1)
14 880	14 720	14 520	14 300	13 440	11 730	10 240	8820	7540	6470	5480	4620	3910	3420	31·7–44·4	15·9	2¼ Cr–1 Mo (Note 2)
14 880	14 720	14 520	14 300	14 090	12 600	10 740	9040	7830	6550	5760	4910			29·8–39·4	17·8	½ Cr–½ Mo–¼V

Notes: 1. Annealed condition. 2. Normalised and tempered condition.

TABLE E 5.4

STANDARD PIPE SIZES—OUTSIDE DIAMETER				MINIMUM OVERRIDING NOMINAL THICKNESS	
Exceeding		Not exceeding			
mm	(in)	mm	(in)	mm	(in)
—	—	10,2	(0·406)	1,6	(0·064)
10,2	(0·406)	17,2	(0·688)	1,8	(0·072)
17,2	(0·688)	26,9	(1·063)	2,0	(0·08)
26,9	(1·063)	33,7	(1·344)	2,3	(0·092)
33,7	(1·344)	54,0	(2·125)	2,6	(0·104)
54,0	(2·125)	76,1	(3·0)	2,9	(0·116)
76,1	(3·0)	88,9	(3·5)	3,2	(0·128)
88,9	(3·5)	114,3	(4·5)	3,6	(0·144)
114,3	(4·5)	139,7	(5·5)	4,0	(0·160)
139,7	(5·5)	168,3	(6·625)	4,5	(0·176)
168,3	(6·625)	193,7	(7·625)	5,4	(0·212)
193,7	(7·625)	219,1	(8·625)	5,9	(0·232)
219,1	(8·625)	273,0	(10·75)	6,3	(0·250)
273,0	(10·75)	323,9	(12·75)	7,1	(0·280)
323,9	(12·75)	368,0	(14·5)	8,0	(0·312)
368,0	(14·5)	419,0	(16·5)	8,8	(0·344)

TABLE E 5.5

Minimum bending radii for steel pipes of thickness determined by the formulæ in E 513.

1		2		3		4		5	
Outside Diameter		Radius measured to centreline of pipe		Outside Diameter		Radii measured to centreline of pipe			
		$T_b = 1{,}125T$ All thicknesses				$T_b = 1{,}125T$ All thicknesses		$T_b = 1{,}1T$ $T_b = 35$ mm (1·375 in) or above	
mm	(in)	mm	(in)	mm	(in)	mm	(in)	mm	(in)
26,9	(1·063)	63	(2·5)	244,5	(9·625)	810	(32)	1140	(45)
33,7	(1·344)	76	(3·0)	273,0	(10·75)	1020	(40)	1270	(50)
42,4	(1·688)	101	(4·0)	298,5	(11·75)	1120	(44)	1400	(55)
48,3	(1·906)	114	(4·5)	323,9	(12·75)	1220	(48)	1520	(60)
60,3	(2·375)	152	(6·0)	355,6	(14·0)	1500	(59)	1780	(70)
76,1	(3·0)	190	(7·5)	381,0	(15·0)	1600	(63)	1900	(75)
88,9	(3·5)	228	(9·0)	406,4	(16·0)	1730	(68)	2030	(80)
101,6	(4·0)	267	(10·5)	457,2	(18·0)	2030	(80)	2280	(90)
114,3	(4·5)	305	(12·0)						
127,0	(5·0)	355	(14·0)						
139,7	(5·5)	380	(15·0)						
152,4	(6·0)	430	(17·0)						
165,1	(6·5)	460	(18·0)						
168,3	(6·625)	460	(18·0)						
177,8	(7·0)	580	(23·0)						
193,7	(7·625)	630	(25·0)						
219,1	(8·625)	710	(28·0)						

514 Any proposal to bend pipes to smaller radii than shown in Table E 5.5 will be the subject of special consideration and further allowance is to be made for thinning at the outside of the bend, except where it can be demonstrated that the use of a thickness T_b would not reduce the thickness below T at any point after bending.

There is a minimum thickness for each size of pipe dependent on bending procedure below which the allowance for thinning will be exceeded, and in such cases the radius given in Table E 5.5 is to be increased where necessary to ensure that the thickness is not below T at any point after bending.

Pipe Joints

515 Joints in pressure pipe lines may be made by bolted flanges or by butt welds between pipes or between pipes and valve chests, or other fittings, but with the latter system it is desirable that a few flanged joints be provided at suitable positions to facilitate installation, cold "pull up" and inspection at periodical surveys.

Where pressure pipe lines are assembled and butt welded in place the piping is to be arranged well clear of adjacent structures, to permit sufficient access for preheating, welding, heat treatment and examination of the joints.

When hydraulic testing the pipe lines at periodical surveys, the test pressure P_T is to be in accordance with 523 or twice the design pressure, whichever is the lesser; terminal valves should be capable of withstanding the same test pressure when closed. In the supporting and securing arrangements for the pipe lines, provision is to be made for these hydraulic test conditions.

Steel Pipe Flanges

516 Flanges are to be weldless and of material suitable for the design temperature. They may be attached to pipes by screwing and expanding or by welding depending upon the pressures and temperatures for which the various types are acceptable as indicated in Table E 5.6. Acceptable methods of attachment are illustrated in Fig. E 5.1.

If backing rings are used with flange type (a) they are to fit closely to the bore of the pipe and should be removed after welding. The rings are to be made of the same material as the pipes or of good quality mild steel having a sulphur content not greater than 0,06 per cent. The use of flange types (b) and (c) with alloy steel pipes is limited to pipes up to and including 150 mm (6 in) outside diameter. Flange types (c) and (e) are unsuitable for pipes under 75 mm (3 in) bore.

TABLE E 5.6

Type of Flange Attachment	Service and Rating			
	Feed, Air, Oil Fuel and other fluids		Steam	
	Pressure kg/cm² (lb/in²)	Temperature °C (°F)	Pressure kg/cm² (lb/in²)	Temperature °C (°F)
(*a*), (*b*) & (*c*)	All Conditions		All Conditions	
(*d*) & (*e*)	52,5 (750)		38,5 (550)	400 (750)
(*f*)	42 (600)	260 (500)	31,5 (450)	
(*g*)	17,5 (250)		17,5 (250)	260 (500)

Alternative methods of flange attachment and other types of pipe joints may be accepted provided details are submitted for special consideration.

For flange types (b) and (c), dimension X is to be taken as T for carbon steel and 2T for alloy steel pipes but is not to be less than shown in the Table associated with Fig. E 5.1.

For flange type (b), dimension Y is to be taken as T for carbon steel and 2T for alloy steel pipes but is not to be less than 5 mm (0·19 in).

T is to be taken as the rule thickness of the pipe.

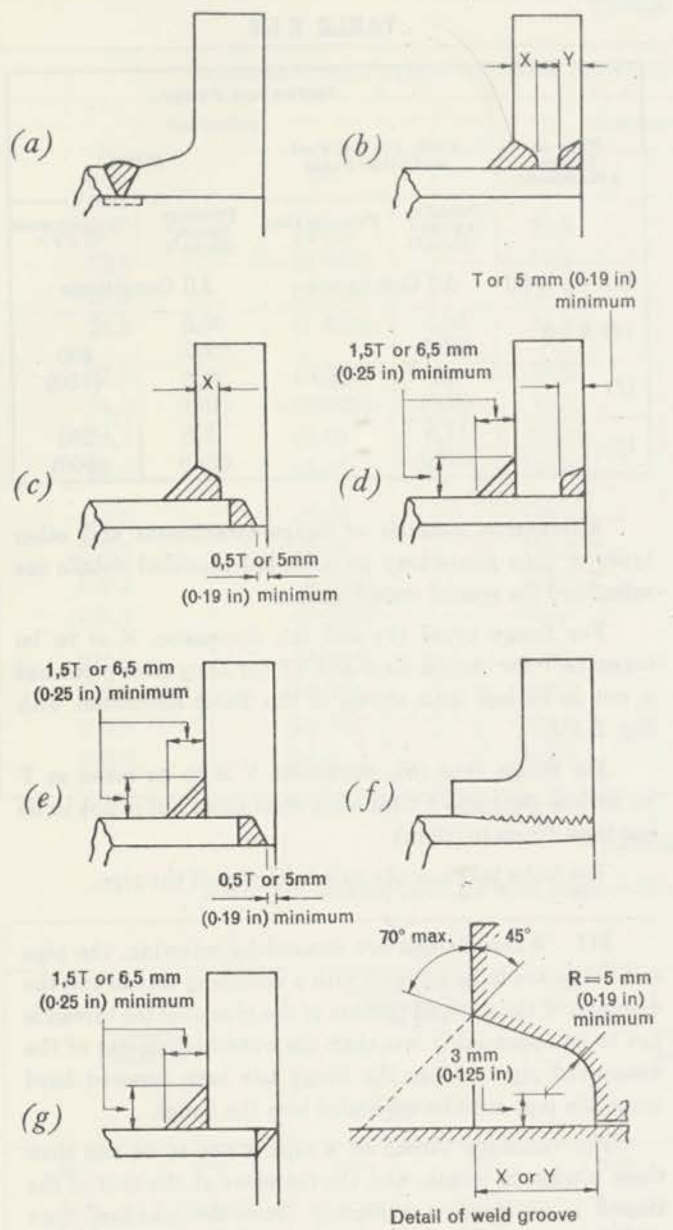
517 Where flanges are secured by screwing, the pipe and flange are to be screwed with a vanishing thread and the diameter of the screwed portion of the pipe over the thread is not to be appreciably less than the outside diameter of the unscrewed pipe. After the flange has been screwed hard home the pipe is to be expanded into the flange.

The vanishing thread on a pipe is not to be less than three pitches in length, and the diameter at the root of the thread is to increase uniformly from the standard root diameter to the diameter at the top of the thread. This may be produced by suitably grinding the dies, and the flange should be tapered out to the same formation.

Welded Flanges, Pipe Joints and Branch Pieces

518 Welding may be carried out by means of the shielded metal arc, inert gas metal arc, oxy-acetylene or other approved process, but in general, oxy-acetylene welding is suitable only for flange type (a) and is not to be applied to pipes exceeding 100 mm (4 in) diameter or 9,5 mm (0·375 in) thick.

When flanges are attached by welding or pipe-to-pipe joints are butt welded using the oxy-acetylene or metal arc



Pipe Bore	Dimension X Minimum
13 mm and 19 mm (0·5 in and 0·75 in)	6,5 (0·25 in)
25 mm to 38 mm (1 in to 1·5 in)	8,0 mm (0·3125 in)
50 mm and over (2 in and over)	9,5 mm (0·375 in)

Fig. E 5.1 Acceptable Methods of Attaching Flanges to Steel Pipes

process the filler rods, electrodes and fusible root inserts used are to be suitable for the materials of the parts to be joined.

All welding work is to be carried out in shop or ship in positions free from draughts or rapid changes of temperature.

Preheating under temperature control is to be employed when necessitated by the dimensions and composition of the materials to be welded and is to be effected by a method which ensures uniformity of temperature at the joint. The method of heating and the means adopted for temperature control are to be to the satisfaction of the Surveyors.

Where butt welds are employed in the attachment of flange type (a), in pipe-to-pipe joints or in the construction of branch pieces, the adjacent pieces are to be matched at the bores. This may be effected by drifting, roller expanding or machining provided the pipe wall is not reduced below the designed thickness. If the parts to be joined differ in wall thickness, the thicker wall is to be gradually tapered to that of the thinner at the butt joint. The welding necks of valve chests are to be sufficiently long to ensure that the valves are not distorted as the result of welding and subsequent heat treatment of the joints.

Butt welds may be reinforced externally by additional runs of weld metal. All welds in high pressure and high temperature pipe lines are to have a smooth surface finish and even contour; if necessary they are to be made smooth by grinding. No undercutting of the pipe at the edges of the weld is acceptable.

519 Branches may be attached to pressure pipes by means of welding provided the pipe is reinforced at the branch by a compensating plate or collar or other approved means, or alternatively the thicknesses of pipe and branch are to be increased to maintain the strength of the pipe.

These requirements also apply to fabricated branch pieces.

520 The welding procedure proposed for the attachment of flanges, valve chests and other fittings to pipes, pipes-to-pipes and the fabrication of branch pieces, whether in carbon or alloy steel, is to be approved by the Surveyors in the first instance before work is commenced. For this purpose representative specimens of such parts will be required for examination and test.

The assembly for the weld procedure test and the welding technique should simulate the conditions under which the work is to be done on the installation. Test welds are to be examined for defects by the appropriate method specified in 521. The test welds are then to be sectioned at positions selected by the Surveyor, one surface

of each section being prepared, etched and examined for defects in the weld and heat affected zones. In the case of pipes or branch pieces of alloy steel, mechanical tests and tests to destruction may also be required to demonstrate that the joints are of adequate strength. Check tests of the quality of the work of the welders are to be carried out periodically at the Surveyor's discretion.

521 All welds attaching flanges and branches to alloy steel pipes of 76 mm (3 in) bore and over are to be examined to ensure as far as possible that the welds are satisfactory. These examinations are to be carried out by radiography where practicable or by other approved methods.

All butt welded joints in steam pipe lines, of 76 mm (3 in) bore and over, when made of carbon steel for the design conditions referred to in 508, or of low alloy steel, are to be examined by radiographic or other approved methods. The techniques are to be applied to the satisfaction of the Surveyor and are to be of a sensitivity which is suitable to disclose detrimental defects. For radiographic examinations and required standards of sensitivity, *see* J 420 to J 423.

Fillet welds in fabricated branch pieces are to be examined by magnetic crack detection methods.

Small detrimental defects, if found, are to be cut out and the seam re-welded and re-examined. In the case of major defects the joint is to be re-machined and completely re-welded.

Heat Treatment of Steel Pipes and Branch Pieces

522 Carbon steel pipes and fabricated branch pieces having a thickness of 19 mm (0·75 in) and over are to be stress relieved on completion of welding. Where oxy-acetylene welding has been employed, however, all the pipes and branch pieces are to be normalised on completion of welding in accordance with the requirements of Table Q 7.2.

All alloy steel pipes and fabricated branch pieces are to be carefully and suitably heat treated in accordance with the requirements of Table Q 7.2 after:—

(a) oxy-acetylene welding, or

(b) being heated for forming or bending operations, or

(c) being cold bent to a radius measured at the centre line of the pipe of less than 3,5 D.

After electric arc welding all alloy steel pipes and branch pieces are to be given a stress relieving heat treatment.

Suitable temperatures for stress relieving carbon and alloy steel pipes and branch pieces are given in Table E 5.7 and should be maintained for one hour per 25 mm (1 in) of wall thickness.

TABLE E 5.7

Pipe Steel	Temperature limits for Stress Relieving	
Carbon	580–620°C	(1080–1150°F)
1 Cr–$\frac{1}{2}$ Mo	620–670°C	(1150–1240°F)
2$\frac{1}{4}$ Cr–1 Mo	650–690°C	(1200–1270°F)
$\frac{1}{2}$ Cr–$\frac{1}{2}$ Mo–$\frac{1}{4}$V	650–710°C	(1200–1310°F)

Hydraulic Test Pressures

523 (a) All copper and copper alloy main steam and feed pipes are, on completion, to be tested by hydraulic pressure to not less than twice the design pressure as defined in 506. Other copper and copper alloy pipes are to be similarly tested when intended for design pressures above 10,5 kg/cm² (150 lb/in²).

(b) All steel pressure pipes, with the exception of those stated in (c) below, are on completion to be tested by hydraulic pressure to a pressure P_T determined by the following formula:—

$$P_T = \frac{KP}{2f + P}$$

where P_T = test pressure, in kg/cm² (lb/in²),

P = design pressure, in kg/cm² (lb/in²),

f = allowable stress, in kg/cm² (lb/in²), at the design temperature, determined by 511 (a) and shown in Tables E 5.2 and E 5.3,

K = a constant, depending on the pipe material, as indicated in Tables E 5.8 and E 5.9.

If the individual pipes are assembled and the joints butt welded in place, an additional hydraulic test to a pressure P_T, as indicated above, or to twice the design pressure, whichever is the lesser, is to be applied to the erected pipe line.

(c) Completed oil fuel pipes and heating coil systems, after fitting on board, are to be tested to twice the design pressure (*see* E 310, E 312 and E 335).

Cast Iron Heating Pipes

524 Where it is desired to use pressure pipes of cast iron, details are to be submitted.

TABLE E 5.8

Category I Material

Grade of Steel	Yield Stress		Tensile Strength		Constant K	
	kg/mm²	(ton/in²)	kg/mm²	(ton/in²)	Metric	(British)
Carbon	21,3	(13·5)	35–47	(22·2–29·8)	3160	(45 000)
Carbon	25,2	(16·0)	42–54	(26·7–34·3)	3790	(54 000)
1 Cr–½ Mo	23,6	(15·0)	42–63	(26·7–40·0)	3510	(50 000)
2¼ Cr–1 Mo (NOTE 1)	23,6	(15·0)	42–57	(26·7–36·2)	3510	(50 000)
2¼ Cr–1 Mo (NOTE 2)	26,8	(17·0)	50–70	(31·7–44·4)	4000	(57 000)
½ Cr–½ Mo–¼V	30,0	(19·0)	47–62	(29·8–39·4)	4490	(64 000)

NOTES: 1. Annealed condition.
2. Normalised and tempered condition.

TABLE E 5.9

Category II Material

Grade of Steel	Yield Stress		Tensile Strength		Constant K	
	kg/mm²	(ton/in²)	kg/mm²	(ton/in²)	Metric	(British)
Carbon	16,5	(10·5)	33–45	(21·0–28·6)	2600	(37 000)
Carbon	17,8	(11·3)	35–47	(22·2–29·8)	2670	(38 000)
Carbon	21,5	(13·7)	42–54	(26·7–34·3)	3230	(46 000)
1 Cr–½ Mo	22,5	(14·3)	42–63	(26·7–40·0)	3370	(48 000)
2¼ Cr–1 Mo (NOTE 1)	21,5	(13·7)	42–57	(26·7–36·2)	3230	(46 000)
2¼ Cr–1 Mo (NOTE 2)	25,0	(15·9)	50–70	(31·7–44·4)	3720	(53 000)
½ Cr–½ Mo–¼V	28,0	(17·8)	47–62	(29·8–39·4)	4210	(60 000)

NOTES: 1. Annealed condition.
2. Normalised and tempered condition.

Section 6

STEAM PIPE RANGES

Provision for Expansion

601 In all steam pipe ranges provision is to be made for expansion and contraction to take place without unduly straining the pipes.

Where corrugated pipes are used, particulars are to be submitted.

Drainage

602 The slope of the pipes and the number and position of the drain valves or cocks are to be such that water can be efficiently drained from any portion of the steam pipe range when the ship is in normal trim and is either upright or has a list up to 5 degrees.

Arrangements are to be made for ready access to the drain valves or cocks.

Pipes in way of Holds

603 In general, steam pipes are not to be led through spaces which may be used for cargo, but where it is impracticable to avoid this arrangement, plans are to be submitted for consideration. The pipes are to be efficiently secured and insulated and well protected from mechanical damage. Pipe joints are to be as few as practicable and preferably butt welded. After fitting in place, the pipes are to be tested by hydraulic pressure to a pressure P_T, determined in accordance with E 523.

If these pipes are led through shaft tunnels, pipe tunnels in way of cargo holds or through duct keels, they are to be efficiently secured and insulated.

Reduced Pressure Lines

604 Pipe lines which are situated on the low pressure side of reducing valves and which are not designed to withstand the full pressure at the source of supply are to be fitted with pressure gauges and with relief valves having sufficient discharge capacity to protect the piping against excessive pressure.

Valves and Fittings

605 Valves and fittings intended either for steam pressures above 10,5 kg/cm² (150 lb/in²) or temperatures above 218°C (425°F) are to be of steel, carbon or low alloy, or other approved material suitable for the working temperature.

Castings of bronze, iron and carbon steel may be used within the following limits of temperature and pressure:—

Bronze	218°C 10,5 kg/cm² (425°F 150 lb/in²)
Iron	232°C 10,5 kg/cm² (450°F 150 lb/in²)
Carbon Steel	454°C (850°F) all pressures.

Hydraulic Test Pressure

606 All main steam and feed valves and fittings are to be tested by hydraulic pressure to not less than twice the working pressure as defined in E 506 and E 512. Other valves and fittings are to be similarly tested when intended for working pressures above 10,5 kg/cm² (150 lb/in²).

For the testing of boiler mountings, *see* J 626 and J 639.

Steam for Fire Extinguishing in Cargo Holds

607 Where steam is used for fire extinguishing in cargo holds, provision is to be made to prevent damage to cargo by leakage of steam or by drip.

Details of the proposed precautionary measures are to be submitted.

Section 7

BOILER FEED WATER SYSTEMS

Feed Pumps

701 Two separate means of feed are to be provided for all main and auxiliary boilers which are required for essential services, with the exception of boilers in which steam is generated exclusively by exhaust gases or steam, where one means of feed will be accepted provided an alternative steam supply is available.

702 Two or more feed pumps are to be provided of sufficient capacity to supply the boilers under full load conditions with any one pump out of action.

703 Feed pumps may be worked from the main engines or may be independently driven but at least one of the pumps required in 702 is to be independently driven.

704 In twin screw ships in which there is only one independent feed pump each main engine is to be fitted with a feed pump. Where all the feed pumps are independently driven, the pumps are to be connected to deal with the condensate from both engines or from either engine.

705 Independent feed pumps required for feeding the main boilers are to be fitted with automatic regulators for controlling their output.

706 Where main-engine driven feed pumps are fitted and there is only one independent feed pump, a harbour feed pump or an injector is to be fitted to provide the second means of feed to the boilers which are in use when the main engines are not working.

707 Feed pumps are to be provided with valves or cocks interposed between the pumps and the suction and the discharge pipes so that any pump may be opened up for overhaul while the others continue in operation.

Sea Suctions

708 One of the independent feed pumps is to be provided with an emergency suction to the sea, except in the cases mentioned in 709.

Suctions are also to be provided from this pump to the hotwell or condenser, unless suitable stand-by connections have already been provided for this purpose.

709 The sea suction to a feed pump may be omitted if large reserve feed tanks are provided and an evaporator of adequate capacity is fitted.

Reserve Feed Water

710 All ships fitted with boilers are to be provided with storage space for reserve feed water, the structural and piping arrangements being such that this water cannot be contaminated by oil or oily water. *See* D 939, D 1923 and D 1928 for structural arrangements.

General Service Pump

711 An auxiliary independent feed pump may be used for general service, provided it is not connected to tanks containing oil fuel or cargo oil or to tanks, cofferdams and bilges containing oily water.

The valves on the suction pipes from the hotwell or condenser and the feed drain tank or filter are to be of non-return type.

Filters

712 Where superheated steam is used in main or auxiliary engines of reciprocating type, filters are to be fitted to provide for the continuous filtration of the boiler feed water.

713 Where a direct contact heater is supplied with exhaust steam from engines of reciprocating type, the feed water from the heater is to be led through the filters required by 712 or through additional filters arranged to provide for continuous filtration.

Cross-references

714 For materials, working pressure and test pressure of feed pipes, *see* E 501 to E 523.

For feed water level regulators for water tube boilers, *see* J 636.

Section 8

ENGINE COOLING WATER SYSTEMS

Main Supply

801 Provision is to be made for an adequate supply of cooling water to the main propelling machinery and essential auxiliary engines, also to the lubricating oil and fresh water coolers and air coolers for electric propelling machinery where these coolers are fitted. The cooling water pump(s) may be worked from the engines or be driven independently.

Alternative Supply

802 Provision is also to be made for a separate emergency supply of cooling water from a suitable pump.

When selecting a pump for this purpose, consideration is to be given to the maximum pressure which it can develop if the overboard discharge valve is partly or fully closed and, when necessary, condenser doors, water boxes, etc., are to be protected by an approved device against inadvertent over-pressure. *See* H 839 for the hydraulic test pressure which condensers are required to withstand.

Sea Inlets

803 Not less than two sea inlets are to be provided for the pumps supplying the salt water cooling system, one for the main pump and one for the stand-by pump. Alternatively, the sea inlets may be connected to a suction line available to main and stand-by pumps.

These inlets are to be low inlets and one of them may be the ballast pump or general service pump sea inlet.

Stand-by Fresh Water Pump

804 Where fresh water cooling is employed, a stand-by fresh water pump need not be fitted if there be suitable emergency connections from a salt water system.

Cooling Water Supply to Auxiliaries

805 Where each auxiliary is fitted with a cooling water pump, stand-by means of cooling need not be provided. Where, however, a group of auxiliaries is supplied with

cooling water from a common system, a stand-by cooling water pump is to be provided for this system. This pump may be a suitable general service pump.

The auxiliary cooling water pumps are to be connected to not less than two sea inlets, preferably one on each side of the ship.

Strainers

806 Where sea water is used for the direct cooling of the main engines and essential auxiliary engines, the cooling water suction pipes are to be provided with strainers which can be cleaned without interruption to the cooling water supply.

Relief Valves

807 Cooling water pumps worked from the main engines are to be provided with relief valves on the pump discharge.

Copper and Copper Alloy Piping Systems

808 When non-ferrous pipes are proposed for fresh and sea water piping systems, details of the materials and the duty for which they are intended may be submitted to the Society for approval.

In the selection of components for sea water piping systems, care should be taken to avoid metal combinations which may lead to galvanic corrosion in service.

See Chapter R(D) for Guidance Notes on Metal Pipes for Water Services.

Section 9

LUBRICATING OIL SYSTEMS

Pumps

901 In ships of unrestricted class in which the lubricating oil for the main engines (steam engines, oil engines, turbines or electric propelling motors), is circulated under pressure, a stand-by lubricating oil pump is to be provided where the following conditions apply:—

(a) The lubricating oil pump is independently driven and the total output of the main engines exceeds 500 bhp.

(b) One main engine with a built-in lubricating oil pump is fitted and the output of the engine exceeds 500 bhp.

(c) Two or more main engines each with a built-in lubricating oil pump are fitted and the output of each engine exceeds 500 bhp.

The stand-by pump is to be of sufficient capacity to maintain the supply of oil for normal conditions with any one pump out of action. The pump is to be fitted and connected ready for immediate use but where this is not convenient in the case of high speed oil engines with built-in pumps, a complete spare pump may be accepted for installation of type (c).

Similar provision is to be made where separate lubricating oil systems are employed for piston cooling, the operation of reverse reduction gears, oil operated couplings and controllable pitch propellers, unless approved alternative arrangements are provided.

902 Independently driven pumps of rotary type are to be fitted with a non-return valve on the discharge side of the pump.

Alarms

903 All main and auxiliary engines and turbines intended for essential services are to be provided with means for indicating the lubricating oil pressure supply to them. Where such engines and turbines are of more than 50 horse power, audible and visible alarms are to be fitted to give warning of an appreciable reduction in pressure of the lubricating oil supply. Further, these alarms are to be actuated from the outlet side of any restrictions, such as filters, coolers, etc.

Emergency Supply for Propulsion Turbines and Propulsion Turbo-Generators

904 A suitable emergency supply of lubricating oil is to be arranged to come automatically into use in the event of a failure of the supply from the pump.

The emergency supply may be obtained from a gravity tank containing sufficient oil to maintain adequate lubrication for not less than 6 minutes, and in the case of propulsion turbo-generators until the unloaded turbine comes to rest from its maximum rated running speed.

Alternatively, the supply may be provided by the stand-by pump or by an emergency pump. These pumps are to be so arranged that their availability is not affected by a failure in the power supply.

Filters

905 Where the lubricating oil for main propelling engines is circulated under pressure, provision is to be

made for the efficient filtration of the oil. The filters are to be capable of being cleaned without stopping the engine or reducing the supply of filtered oil to the engine.

906 Where filters are fitted on the discharge side of the lubricating oil pump, a relief valve in close circuit is to be fitted between the pump and the filter if the pump is capable of developing a pressure exceeding the design pressure of the system.

907 In the case of propulsion turbines and their gears, arrangements are to be made for the lubricating oil to pass through magnetic strainers and fine filters.

NOTE:—It is recommended that the openings in the filter elements be not coarser than 50 microns (0·002 in), especially for the supply to turbine thrust bearings.

Pipes and Fittings

908 Extreme care is to be taken to ensure that lubricating oil pipes and fittings, before installation, are free from scale, sand, metal particles and other foreign matter.

Drip Trays

909 In ships built of wood, easily drained metal or metal-lined trays are to be fitted to prevent saturation of the woodwork by leakage from the engine and its filters.

Lubrication of Bearings

910 The arrangements for lubricating bearings and for draining crankcase and other oil sumps of main and auxiliary engines, gear cases, electric generators, motors and other running machinery are to be so designed that lubrication will remain efficient with the ship inclined from the normal at any angle up to 15 degrees transversely and when pitching 10 degrees longitudinally and when rolling up to 22,5 degrees from the vertical.

911 For details of the requirements relating to the lubrication of bearings of electric generators and motors, *see* M 107.

Valves and Cocks

912 Outlet valves and cocks on lubricating oil service tanks, other than double bottom tanks, situated in machinery spaces are to be capable of being closed locally and from positions outside the compartment which will always be accessible in the event of fire occurring in these spaces. Remote controls need only be fitted to outlet valves and cocks which are open in normal service and are not required for other outlets such as those on storage tanks. Instructions for closing the valves or cocks are to be indicated at the valves and cocks and at the remote control positions.

In the case of very small tanks consideration will be given to the omission of remote controls.

Cross-References

913 For air and sounding pipes and gauge glasses, *see* E 404, E 413 and E 415.

Section 10

PUMPING ARRANGEMENTS FOR SHIPS NOT FITTED WITH PROPELLING MACHINERY

Hand Pumps

1001 Where auxiliary power is not provided, hand pumps are to be fitted in number and position as may be required for the efficient drainage of the ship.

The pumps are to be capable of being worked from the upper deck or from positions above the load water line which are at all times readily accessible.

The suction lift is not to exceed 7,3 m (24 ft), and is to be well within the capacity of the pump.

1002 The sizes of the hand pumps are not to be less than given in Table E 10.1.

TABLE E 10.1

Tonnage under Upper Deck	Hand Pumps	
	Diameter of barrel of bucket pump mm (in)	Bore of suction pipe of bucket pumps and semi-rotary pumps mm (in)
Not exceeding 500 tons ...	100 (4)	50 (2)
Above 500 tons but not exceeding 1000 tons ...	115 (4·5)	57 (2·25)
Above 1000 tons but not exceeding 2000 tons ...	125 (5)	65 (2·5)
Above 2000 tons	140 (5·5)	70 (2·75)

Where the ship is closely subdivided into small watertight compartments 50 mm (2 in) bore suctions will be accepted.

Power Pumps

1003 In ships in which auxiliary power is available on board, power pump suctions are to be provided for dealing with the drainage of tanks and of the bilges of the principal compartments.

The pumping arrangements are to be as required for self-propelled ships in so far as these requirements are applicable, duly modified to suit the size and service of the ship.

Details of the pumping arrangements are to be submitted for special consideration.

Section 11

PETROLEUM AND OTHER LIQUID CARGOES HAVING A FLASH POINT BELOW 65,5°C (150°F)

General

1101 The following requirements are based on the assumption that the ships are of normal tanker type having the main propelling machinery aft.

Departures from normal type will require special consideration.

Cargo Oil System

1102 A complete system of piping and pumps is to be fitted for dealing with the cargo oil.

1103 Cargo pump rooms are to be enclosed by oiltight bulkheads and are to have no direct communication with machinery spaces.

1104 Pumps for the purpose of filling or emptying the cargo oil tanks are to be used exclusively for this purpose, except as provided in 1107. They are not to have any connections to compartments outside the range of cargo oil tanks.

Means are to be provided for stopping the cargo oil pumps from a position outside the pump rooms, as well as at the pumps.

1105 The pumps are to be provided with effective escape valves which are to be in close circuit, i.e., discharging to the suction side of the pumps.

1106 Expansion joints or bends are to be provided where necessary in the cargo pipe lines.

Terminal pipes, valves and other fittings in the cargo loading and discharging lines to which shore installation hoses are directly connected are to be of steel or other approved ductile material. They are to be of robust construction and strongly supported.

1107 Provision is to be made for the bilge drainage of the cargo pump rooms by pump or bilge ejector suctions. The cargo pumps or cargo stripping pumps may be used for this purpose, provided the bilge suctions are fitted with screw-down non-return valves and, in addition, an isolating valve or cock be fitted on the pump connection to the bilge chest. The pump room bilges of small tankers may be drained by means of a hand pump having a 50 mm (2 in) bore suction.

Pump room suctions are not to enter machinery spaces.

1108 Pump rooms are to be provided with ready means of access and adequate ventilation.

1109 Ullage plugs or sighting ports are to be provided at each tank to enable the amount of ullage to be ascertained.

Ullage plugs or sighting ports should not be fitted in any enclosed space.

1110 Provision is to be made for the gas freeing of the cargo oil tanks when the cargo has been discharged and for the ventilation and gas freeing of all compartments adjacent to cargo oil tanks.

1111 Vapour pipes are to be fitted to cargo oil tanks and connected through shut-off valves or cocks or pressure-vacuum valves to a vapour line led up the mast or other post to a safe height above the weather deck. The outlets from these vapour mains are to be provided with readily renewable wire gauze or safety heads of approved types. If alternative means of dealing with the vapour are desired, details are to be submitted.

Bilge, Ballast, Oil Fuel and other Piping not within the Cargo Oil System

1112 The pumping arrangements in the machinery space and at the forward end of the ship are to comply with the requirements for general cargo ships in so far as they are applicable and with the special requirements detailed in 1113 to 1117.

1113 A separate power pump is to be fitted in a suitable compartment forward of the cargo tanks to deal with bilge drainage, water ballast and oil fuel pumping at the fore end of the ship.

In small tankers, a forward power pump may be dispensed with, provided suitable alternative arrangements are made, details of which are to be submitted.

1114 Where deep cofferdams can be filled with water ballast, a ballast pump in the main engine room may be used for emptying the after cofferdam, provided the suction be led direct to the pump and not to an engine room pipe system. The ballast pump in the forward pump room may be used for emptying the forward cofferdam.

1115 Cofferdams are not to have any direct connections to the cargo oil tanks or cargo oil lines.

Where intended to be dry compartments, after cofferdams adjacent to the pump room may be drained by a cargo pump, provided isolating arrangements are fitted in the bilge system as required by 1107; forward cofferdams may be drained by the bilge and ballast pump in the forward pump room. Alternatively, cofferdams may be drained by hand pumps or bilge ejectors.

Cofferdams are to be provided with sounding pipes and with air pipes led to the open. These air pipes are to be fitted with wire gauze diaphragms at their outlets.

1116 Bilge, ballast, oil fuel and other piping connected to the pumps at the ends of the ship are not to pass through the cargo oil tanks or have any connection with these tanks.

Cargo oil pipes are not to pass through ballast or oil fuel tanks or through compartments which are external to the cargo oil system.

1117 The oil fuel bunkering system is to be entirely separate from the cargo oil system.

Steam and Exhaust Piping

1118 Where heating coils are provided in the cargo oil tanks they are to be made and fitted under the usual conditions of survey and testing. (*See* E 334 to E 336, E 524 and E 601 to E 607.)

An observation tank is to be provided for the heating coil drains and is to be situated in a well ventilated and well lighted part of the machinery space remote from the boilers.

Spectacle flanges are to be provided in the main steam and exhaust pipes to the cargo oil heating system, at a suitable position forward of the machinery space bulkhead, so that the lines can be blanked off in circumstances where cargo oil does not require to be heated or where heating coils are not fitted in the tanks.

1119 Steaming out and fire extinguishing connections for cargo oil tanks or cargo oil pipe lines are to be fitted with valves of non-return type and the main supply to these connections is to be fitted with a master valve placed in a readily accessible position clear of the tanks.

1120 In the cargo pump rooms, drain pipes from steam or exhaust pipes or from the steam cylinders of the pumps are to terminate well above the level of the bilges.

Motive Power of Cargo Oil Pumps

1121 Where the cargo oil pumps are not driven by steam, plans of the arrangements for driving the pumps are to be submitted.

1122 Where cargo pumps are driven by shafting which passes through a pump room bulkhead or deck, gastight glands with efficient means of lubrication are to be fitted to the shaft at the pump room plating.

Auxiliary Machinery outside Main Engine Room

1123 Oil engines are not to be situated within pump rooms, cofferdams or other spaces liable to contain petroleum or other explosive vapours.

(For requirements for electrical equipment within such spaces, *see* M 16.)

Section 12

LIQUEFIED GASES

General

1201 The following requirements are intended primarily for liquefied Methane, Propane, Butane and other petroleum gases but may be applied to other liquefied gases with comparable properties and carrying hazards subject to special consideration in each case.

PART 1

LIQUEFIED PETROLEUM GASES CARRIED IN INDEPENDENT SPHERICAL OR CYLINDRICAL TYPE TANKS AT PRESSURES ABOVE 0,7 kg/cm^2 (10 lb/in^2) AND AT AMBIENT OR LOWER TEMPERATURES

Plans

1202 Plans showing filling, discharging, venting and inerting pipe arrangements, together with particulars of the intended cargo, maximum vapour pressure and minimum liquid temperature are to be submitted.

Hold Drainage

1203 Provision is to be made for the drainage of holds in which the cargo tanks are situated. Normal drainage is to be effected by hand pumps, bilge ejectors or other approved

means. Hand pumps are to be made of gunmetal or other non-ferrous material and are to be fitted on deck having discharges directly overboard. Bilge ejectors are to be fitted in the holds and may be operated by steam or water.

1204 In addition to the above requirements, bilge suctions as required by E 2 are to be provided for use in an emergency. These suctions are to be led direct to the bilge pump suction chest and are to be blanked off in normal service by spectacle blank flanges in readily accessible positions in the machinery space. Screw-lift valves are to be fitted between the spectacle flanges and the bulkhead so that the pipes can be isolated if it is necessary to change over the spectacle flanges. Notice plates are to be fitted in the vicinity of the valves stating that the bilge suctions are not to be used except in case of grave emergency.

A brass rod is to be provided for sounding the holds.

Connections to Cargo Tanks

1205 Cargo tanks are to be provided with the necessary connections for liquid and gas lines, relief valves, liquid level gauging devices, pressure gauges and thermometers.

1206 All connections are to be situated above the weather deck and protected from damage.

Shut-off Valves

1207 Connections for filling and emptying the cargo tanks of liquid or gas are to be fitted with double shut-off valves: one is to be a manually operated shut-off valve and the other one of the following:—

(*a*) a remote controlled valve which is capable of being closed from the loading station and at least two other widely separated positions on the upper deck, or

(*b*) an excess flow valve which will close automatically and prevent the tank emptying in the event of a pipe breaking.

In the case of single purpose connections which are required only for the inlet of liquid or gas a non-return valve would be accepted in place of (*a*) or (*b*) above.

Shut-off valves are to be fitted with legible nameplates in prominent positions.

Pressure Relief Valves

1208 Each cargo tank is to be protected by one or more pressure relief valves of approved design and capacity discharging into a vapour relief main led up the mast or other post to a safe height above the weather deck and well removed from possible sources of ignition.

The relief valves should be of sufficient capacity to discharge the vapours formed by exposure of the cargo tank walls to fire. Calculations on which the area of the valves are based are to be submitted.

In every case the combined discharge capacity of the pressure relief valves is to be sufficient to prevent a rise of pressure in the tank to more than 10 per cent above the design vapour pressure.

The discharge capacity of a pressure relief valve is to be established by type tests carried out in the presence of the Surveyors or by an independent authority recognised by the Society.

Pressure relief valve connections are to be attached to the tanks near the highest part of the vapour space.

Shut-off valves are not to be fitted between the tanks and the pressure relief valves unless there are two or more relief valves per tank and the shut-off arrangements are so devised that pressure relief valves having the required discharge capacity are always in communication with the tank.

Shut-off valves are not to be fitted between the pressure relief valves and the vapour relief main outlet.

Each pressure relief valve is to be tested in the presence of the Surveyors to demonstrate that it commences to discharge at a pressure not more than 3 per cent above the maximum vapour pressure for which the tanks have been approved.

Vacuum Relief Valves

1209 Consideration should be given to the ability of the cargo tanks to withstand any vacuum which may arise in service or when the tanks are being gas freed. Where necessary, vacuum relief valves are to be fitted and vacuum relief obtained from a supply of cargo gas or an inert gas system.

Vapour Relief Systems

1210 The vapour relief main is to have a cross-sectional area equal to the combined area of the branch vapour relief pipes, but if there are three or more cargo tanks the following percentage reductions in the area of the vapour relief main will be allowed:—

3	cargo tanks	10%	reduction
4	,,	20%	,,
5	,,	30%	,,
6 or more	,,	40%	,,

The vapour relief system outlet is to be arranged to discharge the gases in a direction above the horizontal and the outlet is to be fitted with a flameproof wire gauze diaphragm and protected from the weather. Suitable drainage arrangements for condensate water are to be provided for the vapour relief lines.

Level Gauges

1211 Liquid level gauging devices are to be of approved type and are to indicate the maximum level to which the tank may be filled having regard to the nature of the cargo and its temperature.

Pressure Gauges

1212 Pressure gauges are to be marked with the working pressure of the tank. Pressure gauge connections are to be fitted with a manually operated shut-off valve.

Cargo Handling System

1213 A complete cargo handling system is to be provided for dealing with the cargo. The system is to be used exclusively for this purpose and is not to have connections to compartments outside the range of the cargo tanks.

Certain items in the system may be inaccessible with cargo on board and where such items are of new design or have not been previously subjected to working conditions similar to those contemplated in service (e.g. pumps and associated driving equipment), prototype tests are to be carried out and the results submitted for approval.

All piping in the cargo handling system is to be situated above the weather deck.

1214 All materials used in the piping systems must be suitable for the proposed service. Where the operating metal temperature is below 0°C (32°F), specifications of the materials for pipes and fittings giving chemical composition and mechanical properties at the service temperature are to be submitted for approval.

1215 All piping, valves and fittings are to be suitable for the maximum pressure to which the system may be subjected, but not, in any case, less than a pressure of 10,5 kg/cm^2 (150 lb/in^2).

Piping subject to pressure is to be of seamless or other approved type and is to comply with the requirements of E 5.

Valves and fittings are to be of steel or other approved ductile material.

1216 Joints may be of butt-welded or flanged type. Couplings of approved type may be used for joints 38 mm (1·5 in) diameter or smaller. Low grade screwed joints are not acceptable.

1217 Provision is to be made in the pipe lines for the effects of expansion and contraction. If expansion pieces are used they are to be of the bellows type. All piping is to be suitably supported and secured.

1218 Low temperature pipes are to be protected against external corrosion, adequately insulated and provided with temperature isolation from the hull. Drip trays are to be fitted where cargo leakage or spillage is likely to occur.

1219 Sections of piping which may contain liquid gas and which can be isolated are to be provided with relief valves discharging to the vapour relief main or other safe position.

1220 Connections are to be provided so that the cargo tanks and the cargo handling system can be purged with an inert gas. Provision is also to be made for the gas-freeing of the cargo tanks.

1221 Terminal pipes, valves and fittings in the cargo handling system, to which shore installation hoses are directly connected, are to be of robust construction and strongly supported.

Suitable arrangements are to be provided for relieving the liquid and gas lines of internal pressure before the shore installation hoses are disconnected.

Earthing of Tanks and Pipes

1222 Where tanks and pipes are separated from the hull structure by insulating materials they are to be effectively earthed to the hull by at least two earthing connections as a precaution against the effects of static charges.

Cargo Pumps and Gas Compressors

1223 Pumps and compressors may be installed on the open deck provided they are suitably located and protected from mechanical damage. Alternatively, the pumps and compressors may be fitted in a well-ventilated compartment outside the machinery space. This compartment is to be treated as a dangerous space to which the requirements of M 16 for electrical equipment are applicable.

1224 Where pumps and compressors are driven by shafting which passes through a bulkhead, gastight glands with efficient means of lubrication are to be fitted to the shafts in way of the bulkhead.

1225 The pumps are to be fitted with relief valves if they are capable of developing a discharge pressure greater than the design pressure of the piping system. The relief valves are to discharge to the suction side of the pumps.

1226 Compressors are to be fitted with relief valves discharging to the vapour relief main, or other safe position. The relief valves are to be so proportioned and adjusted that the accumulation with the outlet valves closed will not exceed 10 per cent of the maximum working pressure.

1227 The pumps and compressors are to be capable of being stopped from the loading station and from a position outside the range of the cargo tanks.

Refrigeration Equipment and Piping

1228 Where the cargo is refrigerated or the boil-off is re-liquefied, the arrangements will be specially considered. In ships classed for unrestricted service the capacity of the refrigerating machines is to be based on a sea temperature of 30°C (86°F) and on an ambient air temperature of 45°C (113°F). Two or more refrigerating units are to be provided of capacity sufficient to maintain the liquid cargo at the carrying temperature with any one unit out of use.

PART 2

LIQUEFIED METHANE AND PETROLEUM GASES CARRIED IN INDEPENDENT RECTANGULAR TYPE TANKS AT PRESSURES OF 0,7 kg/cm^2 (10 lb/in^2) OR LESS AND AT TEMPERATURES BELOW AMBIENT

The following paragraphs of Part 1 are applicable:—

Plans	1202
Connections to Cargo Tanks ...	1205 and 1206
Pressure Relief Valves	1208
Vacuum Relief Valves	1209
Vapour Relief System	1210
Cargo Piping System	1214 to 1221 inclusive
Earthing of Tanks and Pipes ...	1222
Refrigeration Equipment and Piping	1228

Shut-off Valves

1229 Each cargo tank is to be provided with separate connections for cooling down, filling and discharge purposes. These connections are to have shut-off valves or cocks manually controlled and fitted with legible nameplates in a prominent position.

Filling connections are to be provided with internal pipes led to the bottom of the tanks.

Level Gauges

1230 An approved liquid level gauging device of the closed type is to be provided for each tank. This gauge should be arranged to give audible and visible warning of the high and low liquid levels in the tank.

An independent high level alarm device is also to be provided for each tank which, besides giving audible and visible warning of over-filling, is capable of closing the terminal valve at the cargo loading station.

Liquid level gauging and alarm devices are to be adequately protected against damage.

Pressure Gauges

1231 Means are to be provided for indicating the pressure in each cargo tank and containment space.

Thermometers

1232 Thermometers are to be of the remote reading type and are to be marked with the minimum permitted carrying temperature for the tank.

Instrument and Control Rooms

1233 Gas detection, pressure recording, safety and alarm devices, etc., are to be installed in a well ventilated room in an approved position.

Where gas detecting devices are fitted in a room containing electrical equipment which is not intrinsically safe, the arrangements are to be such that there is no possibility of gas leakage reaching the electrical equipment. Details are to be submitted.

Cargo Handling System

1234 A complete cargo handling system is to be provided for dealing with the cargo. The system is to be used exclusively for this purpose and is not to have connections to compartments outside the range of the cargo tanks.

Certain items in the system may be inaccessible with cargo on board and where such items are of new design or have not been previously subjected to working conditions similar to those contemplated in service (e.g. pumps and associated driving equipment), prototype tests are to be carried out and the results submitted for approval.

Terminal valves at the loading station are to be capable of being closed locally and from at least two other widely-separated positions on the upper deck.

All piping in the cargo handling system is to be situated above the weather deck.

Emergency Discharge of Cargo

1235 Where cargo tanks are surrounded by void spaces, provision is to be made for draining such spaces in the event of tank leakage or rupture.

Arrangements are to be made so that the liquid cargo can be discharged overboard in an emergency. The discharge nozzle should preferably be at the stern of the ship and so designed that the liquid discharge will reach the water as far from the ship as possible.

Cargo Pumps

1236 All cargo pumps are to be capable of being stopped from the loading station and from a position outside the range of the cargo tanks. The pumps are to be fitted with relief valves if they are capable of developing a discharge pressure greater than the design pressure of the piping system. The relief valves are to discharge to the suction side of the pump.

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Stand-by means for pumping out each cargo tank are to be provided.

1237 In the case of deep well pumps driven from positions above the cargo tanks, gastight glands with efficient means of lubrication are to be provided where the driving shafts enter the tanks.

1238 If the cargo pumps are driven by submerged electric motors, the arrangements will be subject to special consideration and must ensure that under all conditions air will not be admitted to the cargo tanks.

Cross-reference

1239 Cargo tanks are to be constructed as required by J 7 or D 71 whichever is applicable.

Ventilation arrangements are to comply with ... D 72

Electrical arrangements are to comply with ... M 16

The use of Methane as fuel for propulsion purposes ... ... *see* R (A)

Chapter F

FIRE PROTECTION, DETECTION AND EXTINCTION

PART 1

FIRE DETECTION AND EXTINCTION IN PASSENGER, CARGO AND OTHER SHIPS

Section 1

GENERAL

101 The requirements of Part 1 of this Chapter apply to passenger and cargo ships to be classed for unrestricted service.

102 While the requirements satisfy the regulations of the International Convention for the Safety of Life at Sea, 1960, attention should also be given to any relevant statutory requirements of the National Authority of the country in which the ship is to be registered. Compliance with these statutory requirements may be accepted as meeting the requirements of this Chapter.

103 Consideration will be given to special cases where the arrangements are equivalent to those required by these Rules. Consideration will also be given to fire extinguishing equipment and arrangements for small ships and ships to be classed for restricted or special service.

104 Fire fighting appliances—hoses, extinguishers, gas cylinders, emergency pumps, breathing apparatus, fireman's axe, etc.—which have been approved by a National Authority as complying with the regulations of the International Convention for Safety of Life at Sea, 1960, may be accepted as meeting the requirements of this Chapter.

105 Where it is proposed to apply centralised, bridge, or automatic controls to propulsion machinery and essential auxiliaries and it is intended that the engine and/or boiler rooms will not be continuously manned at sea, an approved fire detection system, in accordance with F 326 to F 328, is to be provided in these spaces (*see* Chapter L).

NOTE.—Having regard to the greater fire risk when a ship is in port, and the possibly reduced level of manning, it is recommended that an approved fire detection system, in accordance with F 326 to F 328, should be provided in engine and/or boiler rooms not fitted with the type of controls indicated in 105.

Section 2

PUMPS, WATER SERVICE PIPES, HYDRANTS AND HOSES

Total Capacity of Fire Pumps

201 In a passenger ship, the required fire pumps of F 4 are to be capable of delivering for fire fighting purposes a quantity of water not less than two-thirds of the total quantity required to be dealt with by the bilge pumps when employed for bilge pumping. (*See* E 239 for number and capacity of bilge pumps.)

The fire pumps are to be capable of developing the pressures in the fire main as required by 206.

202 In a cargo ship, the required fire pumps of F 5, other than the emergency pump (if any), are to be capable of delivering for fire fighting purposes a quantity of water not less than two-thirds of the total quantity required to be dealt with by the bilge pumps when employed for bilge pumping, except that in cargo ships the total required capacity of the fire pumps need not exceed 180 m^3 (180 tons) per hour. (*See* E 205 for number and capacity of bilge pumps).

The fire pumps are to be capable of developing the pressures in the fire main as required by 206.

Fire Pumps

203 Sanitary, ballast, bilge or general service pumps may be accepted as fire pumps, provided that they are not normally used for pumping oil and that if they are subject to occasional duty for the transfer or pumping of fuel oil, suitable change-over arrangements are fitted.

In ships classed for navigation in ice the fire pump sea inlet valves are to be provided with clearing arrangements as required by H 509 and H 511.

204 Any pump designated as a fire pump (other than any emergency pump required by F 505) is to have a capacity not less than 80 per cent of the total required capacity divided by the number of required fire pumps and in any event is to be capable of delivering at least the two required jets of water. Any deficiency in capacity of one of the fire pumps is to be made good by excess capacity of the other fire pumps. These fire pumps are to be capable of supplying the fire main system under the required conditions.

Where more pumps than required are installed their capacities will be specially considered.

205 Relief valves are to be provided in conjunction with all fire pumps if the pumps are capable of developing a pressure exceeding the design pressure of the water service pipes, hydrants and hoses. These valves are to be so placed and adjusted as to prevent excessive pressure in any part of the fire main system.

Pressure in the Fire Main

206 The fire pumps, associated piping and fire main are to be so designed that the following minimum pressures will be maintained at all hydrants under conditions where the two fire pumps required by 201 or 202 are simultaneously delivering water to the fire main of size required by 207 through adjacent nozzles of sizes required by 215.

Passenger Ships	
4000 tons gross and over ...	3,2 kg/cm² (45 lb/in²).
1000 tons gross and over but under 4000 tons gross	2,8 kg/cm² (40 lb/in²).
Under 1000 tons gross ...	A pressure sufficient to produce a 12,2 m (40 ft) jet throw required by 215 to the satisfaction of the Surveyors.
Cargo Ships	
6000 tons gross and over ...	2,8 kg/cm² (40 lb/in²).
1000 tons gross and over but under 6000 tons gross	2,6 kg/cm² (37 lb/in²).
Under 1000 tons gross ...	A pressure sufficient to produce a 12,2 m (40 ft) jet throw required by 215 to the satisfaction of the Surveyors.

Fire Main

207 The diameter of the fire main is to be based on the required capacity of two fire pumps and the diameters of the water service pipes are to be sufficient to ensure an adequate supply of water for the simultaneous operation of at least two fire hoses. In general, the diameter of the fire main should not be less than that required by the following formula but is in no case to be less than 50 mm (2 in):—

$$d = \frac{L}{1,2} + 25 \text{ mm} \qquad \left(d = \frac{L}{100} + 1 \text{ in}\right)$$

when d = internal diameter of the fire main, in mm (in),

L = Rule length of the ship, in metres (feet).

The diameter of the fire main need not exceed 127 mm (5 in) in cargo ships and 178 mm (7 in) in passenger ships.

208 The fire main is to be situated outside the machinery spaces and the discharge line or lines from the fire pumps are to be fitted with isolating valves at the connections to the fire main. Where the machinery space is situated amidships isolating valves are also to be provided in the fire main so that the hydrants at both ends of the ship may be used simultaneously or separately.

209 The wash deck line may be used as a fire main provided the requirements of this Section are satisfied.

210 All water pipes for fire extinguishing are to be provided with drain valves for use in frosty weather. The valves are to be located where they will not be damaged by cargo.

Number and Position of Hydrants

211 The number and position of the hydrants are to be such that at least two jets of water not emanating from the same hydrant, one of which is to be from a single length of hose, may reach any part of the ship. In ships of 1000 tons gross and over two hydrants are to be provided in the machinery spaces: in smaller ships one hydrant will be accepted.

Pipes and Hydrants

212 Materials readily rendered ineffective by heat are not to be used for fire mains. Where steel pipes are used they are to be galvanised internally and externally. Cast iron pipes are not acceptable. The pipes and hydrants are to be so placed that the fire hoses may be easily coupled to them. In ships where deck cargo may be carried, the positions of the hydrants are to be such that they are always readily accessible and the pipes are to be arranged as far as practicable to avoid risk of damage by such cargo. Unless there is provided one hose and nozzle for each hydrant in the ship there shall be complete interchangeability of hose couplings and nozzles.

213 Valves or cocks are to be fitted in such positions on the pipes that any of the fire hoses may be removed while the fire pumps are at work.

Fire Hoses

214 Fire hoses are to be of leather, seamless hemp, close weave flax canvas, or other approved material. The hoses are to be sufficient in length to project a jet of water to any of the spaces in which they may be required to be used. Their length in general is not to exceed 18,3 m (60 ft). Each hose is to be provided with a nozzle and the necessary couplings. Fire hoses, together with any necessary fittings and tools, are to be kept ready for use in conspicuous positions near the water service hydrants or connections.

Nozzles

215 The nozzles used for extinguishing fires other than oil fires are to have a bore of not less than 12 mm (0·5 in). For accommodation and service spaces, a nozzle size of 12 mm (0·5 in) will normally be adequate but for machinery spaces and exterior locations 12, 16 or 20 mm (0·5, 0·625 or 0·75 in) nozzles may be adopted so as to make full use of the maximum discharge capacity of the fire pumps. The jet throw at any nozzle is to be about 12,2 m (40 ft). Dual purpose nozzles for jet or fog may be adopted.

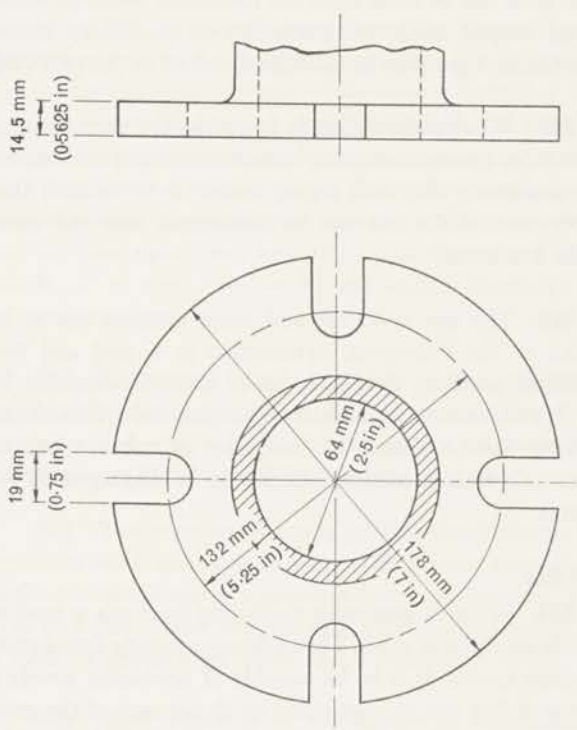


Fig. F 2.1

International Shore Connection

216 The international shore connection required by F 408 and F 509 is to be suitable for a working pressure of 10,5 kg/cm^2 (150 lb/in^2). It is to have on one side a flat faced flange with dimensions as shown in Fig. F 2.1, and on the other side a permanently attached coupling that will fit the ship's hydrants and hose. The connection is to be kept aboard the ship together with a gasket suitable for 10,5 kg/cm^2 (150 lb/in^2) service, together with four 16 mm (0·625 in) bolts, 50 mm (2 in) in length, and eight washers.

Section 3

FIRE EXTINGUISHERS AND EXTINGUISHING SYSTEMS

Fire Extinguishers (Portable and Non-Portable)

301 All fire extinguishers are to be approved types.

If considered necessary, the Committee may require the makers to produce evidence from a recognised independent testing authority regarding the suitability of their appliances.

302 The extinguishers required for use in the machinery spaces of ships burning oil as fuel are to be of a type discharging froth, carbon dioxide gas, dry powder, or other approved medium suitable for extinguishing oil fires.

Fire extinguishers containing an extinguishing medium which either itself or when in use gives off gases harmful to persons are not to be used. For radio rooms and switchboards extinguishers containing not more than 1,136 litres (1 quart) of carbon tetrachloride or similar media may be permitted subject to such extinguishers being additional to any required by F 4 and F 5.

303 The capacity of required portable fluid extinguishers is not to be more than 13,5 litres (3 gallons) and not less than 9 litres (2 gallons). Other extinguishers are not to be in excess of the equivalent portability of the 13,5 litre (3 gallon) fluid extinguisher and are not to be less than the fire extinguishing equivalent of a 9 litre (2 gallon) fluid extinguisher.

304 A spare charge is to be provided for each required portable fire extinguisher which can be readily re-charged on board. If this cannot be done, duplicate extinguishers are to be provided.

305 One of the portable fire extinguishers intended for use in any space is to be stowed near the entrance to that space.

Acceptable Equivalents

306

Froth	Carbon Dioxide
136 litres (30 gallons)	45 kg (100 lb)
45 litres (10 gallons)	16 kg (35 lb)
Portable	4,5 kg (10 lb)

Fire-Smothering Gas or Steam for Machinery and Cargo Spaces

307 Where provision is made for the injection of gas into machinery spaces or gas or steam into cargo spaces for fire extinguishing purposes, the necessary pipes for conveying the gas or steam are to be provided with control valves or cocks which are to be so placed that they will be easily accessible and not readily cut off from use by an outbreak of fire. These control valves or cocks are to be so marked as to indicate clearly the compartments to which the pipes are led. Suitable provision is to be made to prevent inadvertent admission of the gas or steam to any compartment. Where cargo spaces, fitted with smothering equipment for fire protection, are used as passenger spaces the smothering connections are to be blanked during service as a passenger space. Blank flanges fitted in gas or steam distribution pipes are to be of the "spectacle" type. The nuts for the securing bolts are to be of non-corrodible metal.

308 The piping is to be of adequate size and so arranged to provide effective distribution of fire-smothering gas or steam. In holds exceeding 18,3 m (60 ft) in length, there are to be at least two pipes, one of which is to be fitted in the forward part and one in the after part; the steam pipes are to be led well down in the space as remote as possible from the shell. Separate pipes are to be provided for lower hold and 'tween decks. All pipes are to be arranged to be self-draining and are not to be led through refrigerated spaces unless the pipes are specially insulated. Steel distribution pipes are to be galvanised internally and externally and are not to be smaller than 20 mm (0·75 in) bore for carbon dioxide and 25 mm (1 in) bore for steam and inert gas.

In tankers, the piping system is to be so arranged that the gas or steam will be distributed over the surface of the cargo. *See also* F 513.

Carbon Dioxide Gas

309 When carbon dioxide is used as the extinguishing medium in cargo spaces, the quantity of gas available is to be sufficient to give a minimum volume of free gas equal to 30 per cent of the gross volume of the largest cargo compartment in the ship which is capable of being sealed.

310 When carbon dioxide is used as an extinguishing medium for spaces containing boilers or internal combustion type machinery, the quantity of gas carried is to be sufficient to give a minimum volume of free gas equal to the larger of the following, either:—

(1) 40 per cent of the gross volume of the largest space, the volume to include the casing up to the level at which the horizontal area of the casing is 40 per cent or less of that of the space concerned; or

(2) 35 per cent of the entire volume of the largest space including the casing;

provided that the above mentioned percentages may be reduced to 35 per cent and 30 per cent respectively for cargo ships of less than 2000 tons gross; provided also that if two or more spaces containing boilers or internal combustion type machinery are not entirely separate they are to be considered as forming one compartment.

When evaluating the quantity of carbon dioxide gas required for the machinery spaces of motor ships, the free air content of the main starting air receivers is to be added to the above gross space volumes. (*See also* J 640.)

311 When carbon dioxide is used as an extinguishing medium both for cargo spaces and for spaces containing boilers or internal combustion type machinery the quantity of gas need not be more than the maximum required either for the largest cargo compartment or machinery space. The volume of gas is to be calculated at 0,56 m^3/kg (9 ft^3/lb).

312 When carbon dioxide is used as the extinguishing medium for spaces containing boilers or internal combustion type machinery the fixed piping system is to be such that 85 per cent of the gas can be discharged into the space within 2 minutes.

313 The gas cylinders and main controls are to be located to the Surveyors' satisfaction in a cool and well ventilated position, not likely to be made inaccessible by fire. Provision is to be made for changing the cylinders and checking their contents by weighing or other approved means. Operating instructions are to be displayed at the controls.

Inert Gas

314 Where a generator producing inert gas is used to provide smothering gas in a fixed fire-smothering installation for cargo spaces, it is to be capable of producing hourly a volume of free gas at least equal to 25 per cent of the gross volume of the largest compartment protected in this way for a period of 72 hours. The generator is to be located in a position not likely to be made inaccessible by fire.

Steam

315 When steam is used as the extinguishing medium in cargo spaces the boiler or boilers available for supplying steam are to have an evaporation of at least 1 kg of steam per hour for each 0,75 m^3 (1 lb for each 12 ft^3) of the gross volume of the largest cargo compartment in the ship. It is required that steam will be available immediately and will not be dependent on the lighting of boilers and that it can be supplied continuously until the end of the voyage in the required quantity in addition to any steam necessary for the normal requirements of the ship including propulsion and that provision is made for extra feed water necessary to meet this requirement.

Steam is not to be used in spaces containing explosives.

Steam used for fire extinguishing purposes is not to be obtained from a supply of super-heated steam.

Audible Alarms

316 Means are to be provided whereby audible warning is given automatically before fire-smothering gas can be released into the machinery space and any other working space.

Automatic Sprinkler Systems

317 Any automatic water sprinkler system for fire protection is to be designed for immediate use at any time, so that no action on the part of the crew is necessary to set it in operation. Where such a system is fitted, it is to be kept charged at the necessary pressure and is to have provision for a continuous supply of water. The distribution pipes are to be of steel or other approved material of adequate strength and the mains and their branches up to the section control points, if of steel, are to be galvanized internally and externally.

318 The system is to be sub-divided into an approved number of sections, and automatic alarms are to be provided to indicate at one or more suitable points or stations the occurrence or indication of fire, and its location.

319 The pump or pumps to provide the discharge from sprinkler heads are to be so connected as to be brought into action automatically by a pressure drop in the system. There is to be a connection from the ship's fire main provided with a lockable screw-down valve and a non-return valve.

320 Each pump is to be capable of maintaining a sufficient supply of water at the appropriate pressure, at the sprinkler heads, while such number of sprinkler heads as may be approved are in operation.

321 In passenger ships there are not to be less than two sources of power supply for the sea water pumps, air compressors and automatic alarms. Where the sources of power are electrical, these are to be a main generator and an emergency source of power. One supply is to be taken from the main switchboard by separate feeders reserved solely for that purpose. Such feeders are to be run to a change-over switch situated near to the sprinkler unit and the switch shall normally be kept closed to the feeder from the emergency switchboard. The change-over switch is to be clearly labelled, and no other switch except those at the switchboards is to be permitted in these feeders.

322 Sprinkler heads are required to operate at temperatures between 68°C and 93°C (155°F and 200°F) except in drying rooms and other hot spaces. Suitable means for the periodic testing of all automatic arrangements are to be provided.

323 Where a sprinkler system of fire protection is employed in a ship the superstructure of which is constructed in aluminium alloy, the whole unit including the sprinkler pump, tank and air compressor is to be situated in an approved position reasonably remote from the boiler and machinery spaces. If the feeders from the emergency generator to the sprinkler unit pass through any space constituting a fire risk the cables are to be of a fireproof type.

Fixed Froth Fire Extinguishing System

324 Any required fixed froth fire extinguishing system is to be able to discharge a quantity of froth sufficient to cover to a depth of 150 mm (6 in) the largest area over which oil fuel is liable to spread.

325 Such a system is to be controlled from an easily accessible position or positions, outside the space to be protected, which will not be readily cut off by an outbreak of fire. The distribution pipes are to be of steel galvanised internally and externally.

Fire Detection Systems

326 All required fire detection systems are to be capable of automatically indicating the presence or indication of fire and its location. Indicators are to be centralised either on the bridge or in other control stations which are provided with a direct communication with the bridge. The indicators may be distributed among several stations subject to approval by the Surveyors.

327 Electrical equipment used in the operation of required fire detection systems is to have two separate sources of power, one of which should be an emergency source.

328 The alarm system is to operate both audible and visible signals at the main stations referred to in 326. Detection systems for cargo spaces need not have audible alarms. Where it is intended that the engine and/or boiler rooms will not be continuously manned at sea, the alarm system is to operate both audible and visible signals at the station from which the machinery is controlled, which should be in direct communication with the bridge. When control is effected from the bridge only, the alarms must operate also in the Engineer Officers' accommodation.

Fixed Pressure Water-Spraying Systems for Engine Rooms and Boiler Rooms

329 Fixed pressure water-spraying systems for boiler rooms with oil fired boilers and engine rooms with internal combustion type machinery are to be provided with spraying nozzles of an approved type.

330 The number and arrangement of the nozzles are to be to the satisfaction of the Surveyors and be such as to ensure an effective distribution of water in the spaces to be protected. Nozzles are to be fitted above bilges, tank tops and other areas over which oil fuel is liable to spread and also above oil fuel settling and service tanks, heaters, pumping units, purifiers and other main fire hazards in the boiler and engine rooms.

331 The system may be divided into sections, the distribution manifolds of which are to be operated from easily accessible positions outside the spaces to be protected and which will not be readily cut off by an outbreak of fire.

332 The system is to be kept charged at the necessary pressure and the pump supplying the water for the system is to be put automatically into action by a pressure drop in the system.

333 The pump is to be capable of simultaneously supplying at the necessary pressure all sections of the system in any one compartment to be protected. The pump and its controls are to be installed outside the space or spaces to be protected. It is not to be possible for a fire in the space or spaces protected by the water-spraying system to put the system out of action.

334 Special precautions are to be taken to prevent the nozzles from becoming clogged by impurities in the water or corrosion of piping, nozzles, valves and pump.

Fireman's Outfit

335 A fireman's outfit is to consist of a breathing apparatus, a lifeline, a safety lamp and an axe, as described in this paragraph.

The breathing apparatus is to be of an approved type and may be either (1) or (2):—

(1) A smoke helmet or smoke mask which is to be provided with a suitable air pump and a length of air hose sufficient to reach from the open deck, well clear of hatch or doorway, to any part of the holds or machinery spaces. If, in order to comply with this requirement, an air hose exceeding 36,6 m (120 ft) in length would be necessary, a self-contained breathing apparatus is to be substituted or provided in addition.

(2) A self-contained breathing apparatus which is to be capable of functioning for a period of at least 30 minutes. Spare bottles are to be provided except where facilities for re-charging the bottles are available on board ship.

Each breathing apparatus is to have attached to its belt or harness, by means of a snaphook, a fireproof lifeline of sufficient length and strength.

The safety lamp (hand lantern) is to be of an approved type. Such safety lamps are to be electric, and are to have a minimum burning period of three hours.

The axe is to have an insulated handle.

Closing of Openings and Control of Fans

336 Provision is to be made for closing all openings which might admit air to machinery spaces, to other spaces where there is risk of an oil fire and to cargo spaces protected by fire-smothering systems. Skylights and ventilators of machinery spaces including pump rooms in tankers are to be capable of being shut from deck or from a safe position outside these spaces. Provision is to be made for rapidly stopping all fans from positions outside such spaces.

Cross-references

337 For precautionary arrangements relating to oil leakage and outbreaks of fire, *see:—*

D 1926–D 1929, D 2113, D 2642, E 310, E 315–E 319, E 330–E 333, E 337–E 343, E 403–E 405, E 407, E 413–E 414, E 912 and E 1104.

Section 4

REQUIREMENTS FOR PASSENGER SHIPS

Fire Detection and Alarms

401 Manual fire alarms are to be fitted throughout the passenger and crew accommodation to enable the fire patrol to give an alarm immediately to the bridge or fire control station.

402 A fire alarm or fire detecting system is to be provided which will automatically indicate at one or more suitable points or stations, where it can be most quickly observed by officers and crew, the presence or indication of fire and its location in any parts of the ship such as cargo spaces, baggage and store rooms which are not accessible to the patrol system, except where the ship is engaged on voyages of such short duration that it would be unreasonable to apply this requirement.

Fire Pumps and Water Service Pipes

403 A passenger ship is to be provided with fire pumps, water service pipes, hydrants and hoses complying with F 2 and with the following requirements:—

(1) A passenger ship of 4000 tons gross and over is to be provided with at least three independently driven fire pumps and every passenger ship of less than 4000 tons gross with at least two such fire pumps.

(2) In a passenger ship of 1000 tons gross and over the arrangement of sea connections, pumps and sources of power for operating them is to be such as to ensure that a fire in any one compartment will not put all the fire pumps out of action.

(3) In a passenger ship of less than 1000 tons gross, if a fire in any one compartment could put all the pumps out of action, an emergency fire pump having a capacity of not less than 15 m^3 (15 tons) per hour is to be provided.

Fire Hydrants, Hoses and Nozzles

404 A passenger ship is to be provided with such number of fire hoses as are appropriate and sufficient for the type of ship. There is to be at least one fire hose for each of the hydrants required by F 211, and these hoses are to be used only for the purposes of extinguishing fires or testing the fire extinguishing apparatus at fire drills and surveys.

405 In accommodation, service and machinery spaces, the number and position of hydrants are to be such that the requirements of F 211 may be complied with when all watertight doors and all doors in main vertical zone fire bulkheads are closed.

406 In a passenger ship the arrangements are to be such that at least two jets of water can reach any part of any cargo space when empty.

407 All hydrants in the machinery spaces of passenger ships with oil-fired boilers, steam turbine or internal combustion type propelling machinery are to be fitted with hoses having in addition to the nozzles required in F 215 nozzles suitable for spraying water on oil, or alternatively, dual purpose nozzles. One such hydrant is to be provided in the shaft tunnel adjacent to the engine room watertight door.

International Shore Connection

408 A passenger ship of 1000 tons gross and over is to be provided with at least one international shore connection, complying with F 216. Facilities are to be available enabling such a connection to be used on either side of the ship.

Portable Fire Extinguishers in Accommodation and Service Spaces

409 A passenger ship is to be provided in accommodation, radio rooms and service spaces with such approved portable fire extinguishers as the Surveyors may deem to be appropriate and sufficient. In galleys and their sub-division, one or more portable extinguishers suitable for dealing with fires in oil-fired or electric cooking equipment are to be provided.

Fixed Fire-Smothering Arrangements in Cargo Spaces

410 The cargo spaces of passenger ships of 1000 tons gross and over are to be protected by a fixed fire-smothering gas system complying with F 3.

411 Where a passenger ship is engaged on voyages of such short duration that it would be unreasonable to apply the requirements of 410 and also in passenger ships of less than 1000 tons gross, the necessity for fire-smothering arrangements in cargo spaces will be specially considered.

Fire Extinguishing Appliances in Boiler Rooms, etc.

412 In spaces where main or auxiliary oil-fired boilers are situated, or in spaces containing oil fuel units or settling tanks, a passenger ship is to be provided with any one of the following fixed fire extinguishing installations complying with F 3:—

(1) A pressure water spraying system.

(2) A fire-smothering gas installation.

(3) A fixed froth installation supplemented, if necessary, by a fixed or mobile arrangement for pressure water or froth spraying to fight fire above the floor plates.

In each case if the engine and boiler rooms are not entirely separate, or if fuel oil can drain from the boiler room into the engine room bilges, the combined engine and boiler rooms are to be considered as one compartment.

413 There are to be at least two approved portable extinguishers discharging froth or other approved medium suitable for extinguishing oil fires, in each firing space in each boiler room and each space in which a part of the oil fuel installation is situated.

There is not to be less than one approved froth type extinguisher of at least 136 litres (30 gallons) capacity or equivalent in each boiler room. These extinguishers are to be provided with hoses on reels suitable for reaching any part of the boiler room and spaces containing any part of the oil fuel installations.

414 In each firing space there is to be a receptacle containing at least 0,28 m^3 (10 ft^3) of sand, sawdust impregnated with soda or other approved dry material and a scoop for distributing this material. Alternatively, an approved portable extinguisher may be substituted therefor.

Fire Fighting Appliances in Spaces containing Internal Combustion Type Machinery

415 Where internal combustion engines or gas turbines are used, either (1) for main propulsion or (2) for auxiliary purposes associated with a total power not less than 1000 bhp, a passenger ship is to be provided with the following arrangements A and B:—

(A) There is to be one of the fixed arrangements 1, 2 or 3 required by 412.

(B) There is to be in each engine space one approved froth type extinguisher of not less than 45 litres (10 gallons) capacity or equivalent and also one approved portable froth type extinguisher for each 1000 bhp of the engines or part thereof; but the total number of portable extinguishers so supplied is not to be less than two and need not exceed six.

Fire Fighting Arrangements in Spaces containing Steam Machinery

416 Provision is to be made for extinguishing lubricating oil fires in spaces which are separated from boiler rooms by watertight bulkheads when these spaces contain steam turbines or enclosed forced lubricated steam engines using superheated steam. Equipment not less effective than detailed in 415 (B) is to be provided to the Surveyors' satisfaction.

Fireman's Outfits

417 A passenger ship is to carry at least two fireman's outfits each complying with the requirements of F 335. Where the ship exceeds 10 000 tons gross at least three outfits are to be carried and where it exceeds 20 000 tons gross at least four outfits are to be carried. These outfits are to be kept in widely separated places ready for use.

Section 5

REQUIREMENTS FOR CARGO SHIPS

Fire Pumps and Water Service Pipes

501 All cargo ships are to be provided with fire pumps, water service pipes, hydrants and hoses complying in general with F 2.

502 In cargo ships of less than 150 tons gross, one power pump is to be available for fire extinguishing service. If the ship has a restricted class for harbour or river service a suitable hand pump may be substituted for the power pump.

503 In cargo ships of 150 tons gross and over, but less than 1000 tons gross, not less than two power pumps are to be provided, one of which is to be an independent pump.

504 In cargo ships of 1000 tons gross and over not less than two independently driven power pumps are to be provided.

505 In a cargo ship of 1000 tons gross and over if a fire in any one compartment could put all the pumps out of action there is to be an alternative means of providing water for fire fighting. This alternative means is to be a fixed emergency pump independently driven by a compression ignition engine, or other approved means and having a capacity of not less than 15 m^3 (15 tons) per hour in ships of 1000 tons gross to 2000 tons gross, and not less than 25 m^3 (25 tons) per hour for ships above 2000 tons gross. This emergency pump is to be capable of supplying two jets of water to the satisfaction of the Surveyors. The pump should be located remote from the machinery space; e.g. in ships with machinery amidships the pump should be installed in the tunnel or steering gear compartment, and in ships with machinery aft the pump preferably should be located forward. The pump is to be provided with its own sea suction and a discharge to the fire main. The suction lift is not to exceed 6 m (20 ft) with the ship in light draught. The fuel service tank for the engine is to have a capacity for at least 3 hours operation of the emergency pump. In addition sufficient fuel is to be available for at least 12 hours operation of this pump.

Fire Hydrants, Hoses and Nozzles

506 In cargo ships the number of fire hoses to be provided, each complete with couplings and nozzles, is to be one for each 30 m (100 ft) length of the ship and one spare, but in no case less than five in all for cargo ships of 1000 tons gross and over and three in all for smaller ships. These numbers do not include any hoses required in any engine or boiler room. If necessary the number of hoses is to be increased so as to ensure that hoses in sufficient number are available and accessible at all times, having regard to the type of the ship and the nature of the trade on which the ship is employed.

507 In accommodation, service and machinery spaces, the number and position of hydrants are to be such as to comply with the requirements of F 211. In a cargo ship the arrangements are to be such that at least two jets of water can reach any part of any cargo space when empty.

In ships of 2000 tons gross and over a hydrant is to be provided in the shaft tunnel adjacent to the engine room watertight door.

508 All hydrants in the machinery spaces of cargo ships with oil fired boilers or internal combustion type propelling machinery are to be fitted with hoses having in addition to the nozzles required in F 215 nozzles suitable for spraying water on oil, or alternatively, dual purpose nozzles.

International Shore Connection

509 A cargo ship of 1000 tons gross and over is to be provided with at least one international shore connection, complying with F 216. Facilities are to be available enabling such a connection to be used on either side of the ship.

Portable Fire Extinguishers in Accommodation and Service Spaces

510 A cargo ship is to be provided in accommodation, radio rooms and service spaces with a sufficient number of portable fire extinguishers to ensure that at least one extinguisher will be readily available for use in every compartment of the crew and passenger spaces to the Surveyors' satisfaction; in any case, their number is not to be less than five for ships of 1000 tons gross and over and not less than three in ships of under 1000 tons gross.

For galleys and for spaces containing domestic boilers one portable fire extinguisher suitable for dealing with oil fires or fires in electric cooking equipment is to be provided.

Where a sprinkler system is installed the arrangements will be specially considered.

Fixed Fire-Smothering Arrangements in Cargo Spaces

511 Cargo spaces of ships of 2000 tons gross and over are to be protected by a fixed fire smothering system using carbon dioxide, inert gas or steam. The arrangements are to comply with F 3.

512 The requirements of 511 may be waived for the cargo holds of any ship (other than the tanks of a tanker):—

(1) If they are provided with steel hatch covers having fireproof joints and effective means of closing all ventilators and other openings leading to the holds; or

(2) if the ship is constructed and intended solely for carrying such cargoes as ore, coal or grain; or

(3) where the ship is engaged on voyages of such short duration that it would be unreasonable to apply the requirement.

513 The cargo tanks of tankers of 500 tons gross and over are to be protected by a fixed fire smothering system using carbon dioxide, steam or froth. Installations discharging froth externally to the tanks may be accepted. The details of such installations are to be to the satisfaction of the Surveyors (for steam system *see* E 1119).

514 The cargo tanks of liquefied gas carriers are to be protected by a fixed fire smothering gas system and/or dry chemical extinguishing system. Details are to be submitted for approval.

Fire Detection in Cargo Spaces

515 A smoke or fire detection system is to be provided in each cargo space containing explosives and in adjacent cargo spaces.

Fire Extinguishing Appliances in Boiler Rooms, etc.

516 In spaces where main or auxiliary oil-fired boilers are situated, or in spaces containing oil fuel units or settling tanks, a cargo ship is to be provided with any one of the following fixed fire extinguishing installations complying with F 3.

(1) A pressure water spraying system.

(2) A fire-smothering gas installation.

(3) A fixed froth installation supplemented, if necessary, by a fixed or mobile arrangement for pressure water or froth spraying to fight fire above the floor plates.

The fixed installation is to be of type (2) above in all cases where the flash point of the oil fuel is less than 65,5°C (150°F) or where methane gas is used as fuel for the propulsion of methane tankers. (*See* Chapter R (A)).

In each case if the engine and boiler rooms are not entirely separate, or if fuel oil can drain from the boiler room into the engine room bilges, the combined engine and boiler rooms are to be considered as one compartment.

517 There are to be at least two approved portable extinguishers discharging froth or other approved medium suitable for extinguishing oil fires in each firing space in each boiler room and each space in which a part of the oil fuel installation is situated. In addition, there is to be at least one extinguisher of the same description with a capacity of 9 litres (2 gallons) for each burner, provided that the total capacity of the additional extinguisher or extinguishers need not exceed 45 litres (10 gallons) for any one boiler room.

518 In each firing space there is to be a receptacle containing at least 0,28 m^3 (10 ft^3) of sand, sawdust impregnated with soda, or other approved dry material and a scoop for distributing this material. Alternatively, an approved portable extinguisher may be substituted therefor.

Fire Fighting Appliances in Spaces containing Internal Combustion Type Machinery

519 Where internal combustion engines or gas turbines are used, either (1) for main propulsion machinery, or (2) for auxiliary purposes associated with a total power not less than 1000 bhp, a cargo ship of 1000 tons gross and over is to be provided with the following arrangements A and B, and a cargo ship of under 1000 tons gross with arrangement B. For cargo ships of under 150 tons gross the provision of a 45 litre (10 gallon) extinguisher may be waived.

(A) There is to be one of the fixed arrangements 1, 2 or 3 required by 516.

(B) There is to be in each engine space one approved froth type extinguisher of not less than 45 litres (10 gallons) capacity or equivalent and also one approved portable froth extinguisher for each 1000 bhp of the engines or part thereof; but the total number of portable extinguishers so supplied is not to be less than two and need not exceed six.

Fire Fighting Arrangements in Spaces containing Steam Machinery

520 Provision is to be made for extinguishing lubricating oil fires in spaces which are separated from boiler rooms by watertight bulkheads when these spaces contain propulsion turbines or enclosed forced lubricated engines using superheated steam. Equipment not less effective than detailed in arrangement B of 519 is to be provided to the Surveyors' satisfaction.

Fire Fighting Arrangements in Pump Rooms and Compressor Rooms of Tankers

521 The cargo pump rooms in tankers of 500 tons gross and over are to be provided with a fixed, deck operated, fire extinguishing system using steam, water spray, carbon dioxide or other suitable medium.

In addition, two portable foam extinguishers or equivalent are to be provided, one at the pumps and one at the pump room entrance.

522 The cargo pump rooms and compressor rooms in liquefied gas carriers of 500 tons gross and over are to be provided with a fixed remote controlled fire extinguishing system using carbon dioxide or other suitable medium.

In addition, two portable dry chemical extinguishers or equivalent are to be provided in each space.

523 In tankers and liquefied gas carriers of less than 500 tons gross the fire extinguishing arrangements are to be to the satisfaction of the Surveyors.

Fireman's Outfits

524 A cargo ship is to carry at least one fireman's outfit complying with the requirements of F 335. Ships of 4000 tons gross and over are to carry two such outfits which are to be located at widely separated positions.

Section 6

REQUIREMENTS FOR SHIPS NOT FITTED WITH PROPELLING MACHINERY

601 A power pump or hand pump is to be fitted having a suction from the sea and a discharge to deck for fire extinguishing purposes.

Where oil fuel is used for the generation of power, fire extinguishing appliances suitable for fighting oil fires are to be provided to the satisfaction of the Surveyors.

PART 2

FIRE PROTECTION IN PASSENGER, CARGO AND OTHER SHIPS

Section 7

GENERAL

701 Except where otherwise stated, the requirements of Part 2 of this Chapter apply to passenger ships carrying more than 36 passengers, and cargo ships of 4000 tons gross and over, to be classed for unrestricted service.

702 While the requirements satisfy the regulations of the International Convention for the Safety of Life at Sea, 1960, attention should also be given to any relevant statutory requirements of the National Authority of the country in which the ship is to be registered. Compliance with these statutory requirements may be accepted as meeting the requirements of this Chapter.

703 Consideration will be given to special cases where the arrangements are equivalent to those required by these Rules. Consideration will also be given to fire protection arrangements in ships to be classed for restricted or special services.

704 Plans showing the proposed arrangements are to be submitted for approval.

Materials

705 The hull, superstructures, bulkheads, decks and deckhouses are to be of steel or other material which, by itself or due to insulation provided, has structural and fire integrity properties equivalent to steel. In cargo ships the use of other suitable material will be specially considered.

706 Pipes conveying oil or combustible liquids are to be of approved material having regard to the fire risk. Materials readily rendered ineffective by heat are not to be used for overboard scuppers, sanitary discharges and other outlets which are close to the water line and where the failure of the material in the event of fire would give rise to dangers of flooding.

Section 8

REQUIREMENTS FOR PASSENGER SHIPS CARRYING MORE THAN 36 PASSENGERS

Main Vertical Fire Zones and Fire Divisions

801 The hull, superstructures and deckhouses are to be sub-divided into main vertical fire zones, the mean length of which on any one deck does not in general exceed 40 m (131 ft), by "A" Class fire-resisting divisions as defined in the Safety Convention. Steps and recesses are to be kept to a minimum and are to be of "A" Class divisions.

As far as practicable, the bulkheads forming the boundaries of the main vertical fire zones above the bulkhead deck are to be in line with watertight sub-division bulkheads situated immediately below. Such bulkheads are to extend from deck to deck and to the shell or other boundaries.

Openings in "A" Class Fire-Resisting Divisions

802 Where "A" Class divisions are pierced for electric cables, pipes, trunks, ducts, girders, beams, etc., arrangements are to be made to ensure that the fire resistance is not impaired.

803 Dampers are to be fitted in ventilation trunks and ducts passing through main vertical fire zone bulkheads and are to have local control capable of operation from both sides of the bulkhead. The operating positions are to be readily accessible and marked in red lettering. Indicators are to be fitted to show whether the dampers are open or shut.

804 Except for tonnage openings and hatches to cargo, store and baggage spaces, all openings are to be provided with permanently attached means of closing which are to be at least as effective for resisting fires as the divisions in which they are fitted. Where "A" Class divisions are pierced by tonnage openings the means of closure are to be steel plates.

805 Doors and door frames in "A" Class divisions, with the means of securing them closed, are to provide resistance to fire and to the passage of smoke and flame equivalent to that of the bulkheads in which the doors are situated. Watertight doors need not be insulated.

Each door is to be capable of being opened from each side of the bulkhead by one person only. Fire doors in main vertical zone bulkheads other than watertight doors, are to be of the self-closing type with simple and easy means of release from the open position. These doors are to be of approved type, and the self-closing mechanism is to be capable of closing the door against an inclination of 3,5 degrees opposing closure.

Bulkheads within Main Vertical Fire Zones

806 In ships in which Safety Convention Method I or III fire protection arrangement is adopted, and in which an automatic sprinkler system is not to be fitted, the enclosure bulkheads within accommodation spaces, other than those required to be "A" Class fire-resisting divisions, are to be constructed of "B" Class fire-retarding divisions as defined in the Safety Convention. The arrangement of fire-retarding divisions will be specially considered in relation to the method of fire protection adopted.

Accommodation spaces are halls, dining rooms, lounges and similar permanently enclosed spaces, corridors, lavatories, cabins, offices, crew's quarters, barber shops, isolated pantries and lockers and similar spaces.

Separation of Accommodation Spaces from Machinery, Cargo and Service Spaces

807 The boundary bulkheads and decks separating accommodation spaces from machinery, cargo and service spaces are to be "A" Class fire-resisting divisions, the insulating value of which will be specially considered having regard to the nature of the adjacent spaces.

Machinery spaces include all spaces used for propelling, auxiliary or refrigerating machinery, boilers, pumps, workshops, generators, steering gear, ventilation and air conditioning machinery, oil filling stations and similar spaces and trunks to such spaces.

Service spaces are galleys, main pantries, stores, (except isolated pantries and lockers), mail and specie rooms and similar spaces and trunks to such spaces.

Primary deck coverings within accommodation spaces, control stations, stairways and corridors are to be of approved material which will not readily ignite.

Protection of Stairways in Accommodation and Service Spaces

808 Stairways in accommodation and service spaces are to be of steel frame or other approved equivalent construction and are to be within enclosures formed of "A" Class divisions with positive means of closure at all openings from the lowest accommodation deck at least to a level which is directly accessible to the open deck, except that:—

(1) a stairway connecting only two decks need not be enclosed, provided the integrity of the deck is maintained by proper bulkheads or doors at one level;

(2) stairways may be fitted in the open in a public space, provided they lie wholly within such public space.

Stairway enclosures are to have direct communication with the corridors and are to be of sufficient area to prevent congestion having in view the number of persons likely to use them in an emergency, and are to contain as little accommodation, or other enclosed space in which a fire may originate, as practicable.

The insulation value of stairway enclosure bulkheads will be specially considered having regard to the nature of the adjacent spaces. The means for closure at openings in stairway enclosures are to be at least as effective for resisting fire as the bulkheads in which they are fitted. Doors other than watertight doors are to be of the self-closing type, as required for the main vertical fire zone bulkheads in accordance with 805.

The construction and protection of auxiliary stairways which do not form part of the general means of escape will be specially considered.

Protection of Lift Trunks, Light and Air Trunks, Control Stations and Storerooms, etc.

809 Passenger and service lift trunks, vertical trunks for light and air to passenger spaces, etc., are to be of "A" Class fire-resisting divisions. Doors are to be of steel or other equivalent material and when closed are to provide fire resistance at least as effective as the trunks in which they are fitted.

Lift trunks are to be so fitted as to prevent the passage of smoke and flame from one 'tween deck to another and are to be provided with means of closing so as to permit of draught and smoke control. Insulation need not be fitted to lift trunks which are within stairway enclosures.

Where a trunk for light and air communicates with more than one 'tween deck space and where smoke and flame are likely to be conducted from one 'tween deck to another, smoke shutters, suitably placed, are to be fitted so that each space can be isolated in case of fire.

Any other trunk (e.g. for electric cables) are to be so constructed as not to afford passage for fire from one 'tween deck or compartment to another.

810 Control stations are to be separated from the remainder of the ship by "A" Class bulkheads and decks.

Control stations are those spaces in which radio, main navigating or central fire-recording equipment or the emergency generator is located.

811 The boundary bulkheads of baggage rooms, mail rooms, store rooms, paint and lamp lockers, galleys and similar spaces are to be of "A" Class divisions. Spaces containing highly inflammable stores are to be so situated as to minimise the danger to passengers or crew in the event of fire.

Superstructures

812 Superstructures of aluminium alloy will be specially considered in relation to the Safety Convention Method of fire protection adopted. Where the use of aluminium alloy is approved:—

(1) Adequate provision is to be made to ensure that, in the event of fire, arrangements for stowage, launching and embarkation into lifeboats and rafts remain as effective as if the superstructures were constructed of steel; and

(2) Crowns and casings of boiler and machinery spaces are to be of steel adequately insulated, and any openings therein suitably arranged and protected to prevent spread of fire.

(*See* F 323.)

Windows and Sidescuttles

813 All windows and sidescuttles in bulkheads separating accommodation spaces and the weather are to be constructed with metal frames. The glass is to be retained by a metal glazing bead.

814 In spaces containing main propulsion machinery, or oil-fired boilers, or auxiliary internal combustion type of machinery to total horsepower of 1000 or over, the following provisions are to be made:—

(1) skylights are to be capable of being closed from outside the space.

(2) skylights containing glass panels are to be fitted with external shutters of steel or other equivalent material permanently attached.

(3) any windows in casings of such spaces are to be of non-opening type and are to be fitted with external shutters of steel or other equivalent material permanently attached.

(4) in the windows and skylights referred to above, wire-reinforced glass is to be used.

Ventilation Systems

815 The main inlets and outlets of all ventilation systems are to be capable of being closed from outside the space in the event of fire. In general, the ventilation fans are to be so disposed that the ducts reaching the various spaces remain within the same main vertical zone.

816 All power ventilation, except cargo and machinery space ventilation, is to be fitted with master controls so that all fans may be stopped from either of two separate positions situated as far apart as practicable. Two master controls are to be provided for the power ventilation serving machinery spaces, one of which can be operated from a position outside the machinery space.

817 Efficient insulation is to be provided for exhaust ducts from galley ranges where the ducts pass through accommodation spaces.

Incombustible Materials

818 In ships in which Safety Convention Method I fire protection arrangement is adopted, and in which an automatic sprinkler system is not to be fitted, all linings, grounds, ceilings and insulations are to be of incombustible materials except in cargo spaces, mail rooms, baggage rooms, or refrigerated compartments of service spaces.

819 In ships in which Safety Convention Method III fire protection arrangement is adopted, and in which an automatic sprinkler system is not to be fitted, the use of combustible materials of all kinds such as untreated wood, veneers, ceilings, curtains, carpets, etc., is to be reduced as far as practicable. In large public spaces, the grounds and supports to the linings and ceilings are to be of steel or equivalent material. All exposed surfaces in corridors or stairway enclosures and concealed or inaccessible spaces shall have low flame-spread characteristics.

Automatic Sprinkler and Fire Alarm and Detection Systems

820 In ships in which Safety Convention Method II fire protection arrangement is adopted, and in which "B" Class fire-retarding divisions are not to be fitted within accommodation spaces, an automatic sprinkler and fire alarm system of an approved type, and complying with the requirements of F 317 to F 323, is to be installed and so arranged as to protect all enclosed spaces appropriated to the use or service of passengers or crew, except spaces which afford no substantial fire risk. (*See* M 507.)

Automatic Fire Alarm and Fire Detection Systems

821 In ships in which Safety Convention Method III fire protection arrangement is adopted and in which an automatic sprinkler is not to be fitted, a fire-detecting system of an approved type is to be installed and so arranged as to detect the presence of fire in all enclosed spaces appropriated to the use or service of passengers or crew (except spaces which afford no substantial fire risk), and automatically to indicate at one or more points or stations where it could be most quickly observed by officers and crew, the presence or indication of fire and also its location.

Miscellaneous Items

822 In all parts of the ship, paints, varnishes and similar preparations having a nitro-cellulose or other highly inflammable base are not to be used.

823 In all parts of the ship, pipes penetrating "A" or "B" Class fire divisions are to be of approved material having regard to the temperature such fire divisions are required to withstand.

824 In accommodation and service spaces, air spaces enclosed behind ceilings, panellings or linings are to be suitably sub-divided by close-fitting draught stops not more than 13,7 m (45 ft) apart. In the vertical direction, such spaces, including those behind linings of stairways, trunks, etc., are to be closed at each deck. Small holes are to be arranged in ceilings and bulkheading, so that it will be possible, without impairing the efficiency of the fire protection, for the fire patrols to detect any smoke originating in concealed and inaccessible spaces. The concealed surfaces of all bulkheads, linings, panellings, stairways, wood grounds, etc., in accommodation spaces are to have low flame-spread characteristics.

Section 9

PASSENGER SHIPS CARRYING NOT MORE THAN 36 PASSENGERS

901 Passenger ships to be classed for unrestricted service and carrying more than 12 passengers but not more than 36 passengers need comply only with the fire protection requirements in F 705, F 706, F 801 to F 805, F 807, F 809 (first sub-paragraph), F 810 to F 815, F 822 and F 823.

902 In addition, the following provisions shall apply:—

(i) All stairways and means of escape in accommodation and service spaces shall be of steel or other suitable material.

(ii) Power ventilation of machinery spaces shall be capable of being stopped from an easily accessible position outside the machinery spaces.

(iii) Except where all enclosure bulkheads in accommodation spaces conform with the requirements in F 806, an automatic fire detection system conforming with F 402 is to be provided.

26th January, 1967

Section 10

REQUIREMENTS FOR CARGO SHIPS OF OVER 4000 TONS GROSS

Corridor Bulkheads in Accommodation

1001 The corridor bulkheads in accommodation spaces are to be of steel or constructed of "B" class panels. The requirements of "B" class panels are specified in Chapter II Regulation 35 of the Safety of Life at Sea Convention 1960.

Protection of Interior Stairways, Lift Trunks, Galleys, Storerooms, etc.

1002 Interior stairways below the weather deck are to be of steel or other suitable material. Lift trunks within accommodation spaces shall be of steel or equivalent material. Bulkheads of galleys, paint stores, lamp rooms, boatswain's stores when adjacent to accommodation spaces and emergency generator rooms, if any, shall be of steel or equivalent material.

Deck Coverings

1003 Deck coverings within accommodation spaces on the decks forming the crown of machinery and cargo spaces shall be of a type which will not readily ignite.

Ventilation Systems

1004 Means shall be provided for stopping ventilating fans serving machinery and cargo spaces and for closing all doorways, ventilators, annular spaces around funnels and other openings to such spaces. These means shall be capable of being operated from outside such spaces in case of fire.

Paints, etc.

1005 In accommodation and machinery spaces, paints, varnishes and similar preparations having a nitro-cellulose or other highly inflammable base are not to be used.

Section 11

REQUIREMENTS FOR CARGO SHIPS OF 500 TONS TO 4000 TONS GROSS

1101 F 1004 is to be complied with.

Chapter G

CONDITIONS FOR SURVEY OF MACHINERY DURING CONSTRUCTION

Section 1

101 The materials used in the construction of the machinery, boilers and pressure vessels are to comply with the requirements of Chapter Q. Materials, for which provision is not made in Chapter Q, may be accepted after compliance with such tests as may be imposed, under specifications to be approved before the materials are ordered and construction is commenced.

The machinery, boilers and pressure vessels are to be inspected throughout, the boilers and pressure vessels tested by hydraulic pressure, and the machinery tested under full power working conditions by the Society's Engineer Surveyors, who will furnish a report to the Committee. If found satisfactory, the Committee will thereupon grant a certificate, and insert in the Register Book the appropriate class notation, as set forth in Chapter B, indicating that the machinery, boilers and pressure vessels are certified to have been in good order and safe working condition on that date.

102 In cases of machinery which has been built under Special Survey, the distinguishing mark ✠ will be inserted before the appropriate class notation, as set forth in Chapter B.

103 In ships built under Special Survey, the following items of machinery are also to be constructed under Special Survey:—

The main and auxiliary engines and boilers, superheaters, economisers (including press boilers and similar apparatus for floating whale-oil factories), steering engines, air receivers, air compressors, scavenge blowers and superchargers, oil fuel burning units, feed pumps, circulating and cooling water pumps, fire and bilge pumps, air pumps, ballast and oil fuel transfer pumps, water extraction pumps, lubricating oil pumps, fuel valve cooling pumps for oil engines, forced and induced draught fans, evaporators, distiller units, feed water heaters and pressure filters where the foregoing are intended for essential services, domestic boilers intended for working pressures exceeding 3,5 kg/cm^2 (50 lb/in^2) and having heating surfaces greater than 4,65 m^2 (50 ft^2) and athwartship thrust units including prime movers and control mechanism.

Generators of 100 kW and over and motors of 100 hp and over intended for essential services.

Motors intended for coupling to fans for the circulation of air in refrigerated cargo spaces.

Electric slip couplings.

All electric propelling machinery including switchgear, control gear, cables, main and auxiliary generators, motor and exciters.

NOTE.—Auxiliary boilers supply steam to auxiliary services essential to the operation of the ship at sea; but do not supply steam to the main propelling machinery.

Domestic boilers supply steam for purposes not connected in any way with the operation of the ship at sea.

104 In order to facilitate the inspection, plans in triplicate of the following items, together with the necessary particulars of the machinery, including the maximum power and the revolutions per minute, are to be submitted for consideration before the work is commenced:—

- Boilers, superheaters and economisers.
- Air receivers.
- Crank, thrust, intermediate and screw shafting and screw shaft oil gland.
- Clutch and reversing gear with methods of control and flexible coupling.
- Reduction gearing. (*See also* H 302.)
- Propeller (including spare propeller if supplied). (*See also* H 402.)
- General arrangement of shafting showing relative positions of the main engines, flywheel, flexible coupling, gearing, thrust block, line shafting and bearings, stern tube, "A" bracket and propeller, whichever is applicable.
- Torsional vibration calculations for the shafting systems. (*See* H 241 to H 243.)

NOTES—Plans additional to the above should not be submitted unless the machinery is of a novel or special character affecting classification.

For Plans of Pumping and Piping required to be submitted, *see* E 101.

For Steam and Gas Turbines, *see* H 802.

For Welded Structures for Oil Engines, *see* H 702.

For Welded Pressure Vessels, *see* J 104.

For Control Engineering Equipment, *see* L 102.

For Electrical Equipment and Electric Propelling Machinery, *see* M 102.

For Refrigerated Cargo Installations, *see* N 202.

105 Where it is proposed to depart from the requirements of the Rules, the Committee will be prepared to give consideration to the circumstances of any special case.

106 Any novelty in the construction of the machinery boilers or pressure vessels is to be reported to the Committee.

107 The Surveyors are to examine and test the materials and workmanship from the commencement of the work until the final test of the machinery under full power working conditions; any defects, etc., are to be pointed out as early as possible.

108 Where items of machinery are to be manufactured under mass-production or line-production procedures making normal survey methods difficult or inapplicable the Committee will be prepared on application to give consideration to the adoption of an alternative system of examination involving periodical inspection of the works instead of survey of each individual item.

In order to obtain approval the Surveyors will assess the firm's system of checking materials and components received from other works and inspection will be made of all processes, quality and other controls and works' tests which are applied at each stage of manufacture. The Surveyors may request supplementary tests.

Approval will be conditional upon important steel forgings or castings used being obtained from approved works.

109 The Surveyors may also, if requested, compare the work as it progresses with the requirements of the specification agreed upon by the parties concerned, and certify to the conditions thereof, as far as can be seen, being satisfactorily complied with.

110 The machinery and boilers are to be securely fixed to the ship's structure to the satisfaction of the Surveyor. The bed plates, gear cases, thrust blocks and boiler fastenings are to be of robust construction.

111 Refrigerating machinery using a toxic or inflammable refrigerant, such as ammonia, is to be installed in an efficiently ventilated compartment isolated from the propelling machinery spaces and shaft tunnels, and living quarters.

Methyl chloride refrigerant is not to be used.

Machinery using non-toxic and non-inflammable refrigerants will not be subject to restriction on location in general, but proposals to install relatively large plants in propelling machinery spaces will require special consideration.

Cross-references

112 For conditions relating to the survey during construction of Electrical Equipment, Electrical Propelling Machinery and Refrigerating Machinery and Appliances, *see* M 1, M 17 and N 1 respectively.

Chapter H

MAIN AND AUXILIARY ENGINES AND ASSOCIATED MACHINERY COMPONENTS

Scope

The requirements of this Chapter are applicable to main and auxiliary engines including oil engines, steam and gas turbines, gearing and other associated machinery components.

The main and auxiliary engines are to be made in accordance with the requirements contained in the following sections, where applicable:—

Section 1 General Requirements,
,, 2 Shafting for Oil Engine, Turbine and Electric Propulsion Installations,
,, 3 Reduction Gearing for Propelling and Auxiliary Engines,
,, 4 Propellers,
,, 5 Strengthening for Navigation in Ice,
,, 6 General Requirements for Oil Engines and Starting Air Compressors,
,, 7 Welded Structures for Oil Engines,
,, 8 General Requirements for Steam and Gas Turbines.

NOTE:—For steam reciprocating engines, with or without exhaust steam turbines, the appropriate requirements of the Society's Rules for Steel Ships 1969 are to be complied with.

Section 1

GENERAL REQUIREMENTS

Materials

101 Materials for crank shafts, turbine rotors, pinions gear wheels, shafts including line shafting, propellers and other important machinery parts are to be made and tested under the supervision of the Surveyors in accordance with the appropriate requirements of Chapter Q or, in special cases, with an approved specification.

102 Where it is proposed to use non-ferrous metal for shafting, details of the specification and method of manufacture are to be submitted for consideration.

Inspection

103 The surfaces of shafting and other important machinery parts are to be examined when finish machined and, if required by the Surveyors, also in the rough machined condition.

Definitions

104 Where horse power appears in this Chapter it is to be taken as 76 kg m (550 ft lb) per second.

Operating Conditions and Power Ratings

105 In the sections in this Chapter where the dimensions of any particular component are determined on horse power and revolutions per minute, denoted by H and R respectively, the appropriate values to be used in the relevant formulæ are to be derived from the following:—

(*a*) For main propelling machinery, the maximum propulsion shaft or brake horse power and corresponding revolutions per minute for which the machinery is to be classed.

(*b*) For auxiliary machinery, the maximum continuous shaft or brake horse power and corresponding revolutions per minute which will be used in service.

106 Auxiliary engines coupled to electrical generators are to be capable under service conditions of developing continuously the power to drive the generators at full rated output (kW) and in the case of oil engines of developing for a short period (15 mins.) an overload power of not less than 10 per cent (*see* M 106, M 403 and M 404).

Engine builders should satisfy the Surveyors by tests on individual engines that the above requirements, as applicable, can be complied with, due account being taken

of the difference between the temperatures under test conditions and those referred to in the Note below. Alternatively, where it is not practicable to test the engine/generator set as a unit, type tests, e.g. against a brake, representing a particular size and range of engines may be accepted. With oil engines any fuel stop fitted should be set so as to permit the short period overload power of not less than 10 per cent above full rated output (kW) being developed.

NOTE. The rating of main and essential auxiliary machinery intended for installation in seagoing ships to be classed for unrestricted (geographical) service should be based on a sea temperature not less than 30°C (86°F) and an engine room ambient temperature not less than 45°C (113°F). In the case of ships to be classed for restricted service, the rating should be suitable for the temperature conditions associated with the geographical limits of the restricted service. (*See* B 110 and B 111.)

Alignment Gauges and Wear Down Gauges

107 All main and auxiliary oil engines exceeding 300 bhp are to be provided with an alignment gauge which may be either a bridge wear down gauge, or a micrometer clock gauge for use between the crank webs. Only one micrometer clock gauge need be supplied for each ship provided the gauge is suitable for use on all engines.

Main and auxiliary turbines are to be provided with bridge wear down gauges for testing the alignment of the rotors.

Reduction gears with sleeve bearings, for main and auxiliary turbines and oil engines, are to be provided with bridge wear down gauges for testing the internal alignment of the various elements in the gear cases. In certain gears, e.g. gears of the locked train type, the direction of loading on the bearings of a gear element may be such that an accurate indication of its alignment under operating conditions cannot be obtained using the bridge type wear down gauge. In these instances, suitable alternatives such as crown thickness micrometers are to be provided.

The Surveyors are to witness the initial readings of the wear down gauges.

In the case of reduction gearing for main turbines and oil engines, also for auxiliary turbines and oil engines exceeding 300 shp, trammels or other approved means are to be provided by the gear manufacturer in order that the Surveyors may verify that, when chocked and secured to its seating on board ship, no distortion of the gear case has taken place.

Cross-references

108 For means of escape from machinery spaces and communication between bridge and engine room, *see* D 2113 and D 2114.

Section 2

SHAFTING FOR OIL ENGINE, TURBINE AND ELECTRIC PROPULSION INSTALLATIONS

General

The requirements of this Section relate, in particular, to formulæ for determining the diameters of shafting for main propulsion and auxiliary machinery installations but requirements for torsional vibrations, couplings, coupling bolts, keys, keyways, sternbushes and other associated components are also included.

The Section is divided into three parts as follows:—

Part 1 Crank Shafts for Oil Engines.
Paragraph Nos. 201 to 208.

Part 2 Gear and Line Shafting and Associated Components for Oil Engine, Turbine and Electric Propulsion Installations.
Paragraph Nos. 221 to 236.

Part 3 Torsional Vibrations.
Paragraph Nos. 241 to 243.

PART 1

CRANK SHAFTS FOR OIL ENGINES

Material

201 Material specifications for steel crank shafts, forging procedures and heat treatment details are to be submitted.

202 Where it is proposed to make crank shafts of cast iron, the material specification and the dimensions of the shaft are to be submitted for special consideration.

The material specification should state the type of cast iron, the heat treatment, and mechanical properties, including the specified minimum tensile strength appropriate to the section of the crank shaft casting.

Any suitable type of high duty cast iron may be used, provided the minimum specified tensile strength is between 32 and 76 kg/mm² (20 and 48 ton/in²). Crank shafts are to be cast at a foundry approved for the production of cast iron crank shafts and are to be in accordance with Q 8.

Crank Shafts

203 For steel crank shafts of solid forged, cast, semi-built and built construction, also for cast iron crank shafts, the power rating of the engine is not to exceed that given by the following formula:—

$$\frac{H_o}{R_o} = \frac{nE}{5810\ CK_1}\left[\frac{d^3 Z (T + 16)}{7000} - \frac{AK_2 P (l - l_p) D^2}{100\ 000}\right]$$

or in British units:—

$$\frac{H_o}{R_o} = \frac{nE}{5{\cdot}06\ CK_1}\left[\frac{d^3 Z (T + 10)}{310} - \frac{AK_2 P (l - l_p) D^2}{100\ 000}\right]$$

NOTE:—The power rating $\frac{H_o}{R_o}$ is not to be less than the power rating based on H and R as defined in H 105.

where H_o = maximum designed brake horse power,

R_o = revolutions per minute of the crank shaft at maximum designed brake horse power,

n = number of cylinders for 2SCSA engines,

= half the number of cylinders for 4SCSA engines,

E = mechanical efficiency of the engine expressed as a decimal,

A and C = coefficients from Tables H 2.1, H 2.2, H 2.3 or H 2.4 for appropriate cycle and firing order with equal intervals between firing,

$K_1 = 0{,}8 + \frac{u}{3\,d_p} + 0{,}243\sqrt{\frac{d_p}{r}}$ for solid forged steel or cast iron crank shafts and the combined pins and webs of semi-built forged or cast steel crank shafts,

K_1 = 1,8 for shrunk sections of forged or cast steel semi-built and built crank shafts,

d_p = diameter of crank pin, in mm (in),

r = fillet radius at junction of crank web with crank pin, in mm (in). (The fillet radius at junction of journal and crank web is not to be less than r),

$u = d_p + d_j - S$

d_j = diameter of crank journal, in mm (in),

S = length of stroke, in mm (in),

d = minimum diameter of crank shaft pin or journal, whichever is less, or equivalent diameter for hollow shafting, in mm (in),

Z = 1,0 except as follows:—

= 1,15 for die-forged crank shafts and continuous grain-flow crank shafts where these methods of manufacture or processing have been specially approved,

= 1,25 for crank shafts surface-hardened by nitriding where full particulars of the method and process have been approved. (NOTE.—Special consideration will be given to other surface-hardening treatments which include the fillet radii, in allocating an appropriate Z value. If it can be proved that any surface-hardening process will further improve the fatigue characteristics of die-forged or continuous grain flow crank shafts, consideration will be given to the use of a combined Z value),

$= \frac{T + 26{,}5 - 0{,}006\ d}{1{,}23\ (T + 16)}$

$\left(= \frac{T + 16{\cdot}7 - 0{\cdot}1\ d}{1{\cdot}23\ (T + 10)}\ \text{British}\right)$

for cast iron crank shafts.

T = specified minimum tensile strength of crank shaft material, in kg/mm^2 (ton/in^2),

K_2 = 7,0 for shrunk sections of forged or cast steel semi-built and built crank shafts,

$K_2 = QFG\sqrt{\frac{d_p}{r}}$ for solid forged steel or cast iron crank shafts and the combined pins and webs of semi-built forged or cast steel crank shafts,

Q = coefficient from Fig. H 2.1,

(NOTE.—Q is to be taken as 1,0 for all negative values of $\frac{u}{d_p}$ greater than 0,6),

m = depth of recess of fillet into crank web, in mm (in),

F = coefficient from Fig. H 2.2,

b = breadth of web, in mm (in),

G = coefficient from Fig. H 2.3 or Fig. H 2.4,

t = axial thickness of web, in mm (in),

P = maximum combustion pressure, in kg/cm^2 (lb/in^2), at maximum designed brake horse power,

l = span of bearings adjacent to a crank measured from inner edge to inner edge, in mm (in),

l_p = length of crank pin, in mm (in),

D = diameter of cylinder, in mm (in).

Engines having unequal firing intervals or not covered by values of A and C given in Tables H 2.1, H 2.2, H 2.3 or H 2.4 and Vee engines having different firing orders on each bank will receive special consideration.

For Vee engines having minimum firing intervals between two cylinders on one pin different from those given in Tables H 2.3 or H 2.4, the values of A and C may be obtained by interpolation.

204 In designs of crank shafts to which the engine power rating formula in 203 is not directly applicable, detailed design calculations are to be submitted for special consideration.

205 Special consideration will be given to cast iron crank shafts which have been designed and developed for optimum fatigue strength with cranks of the most favourable shape, and some allowance made for the superior strength thereby obtained. Particulars of any relevant tests or experience should be submitted.

Crank Webs of Built and Semi-built steel Shafts

206 Where the crank webs are shrunk on crank pins or journals, the dimensions and yield stress of the material of the crank webs are not to be less than given by the following formulæ for the shrinkage allowance proposed:—

$$t = \frac{d_r^3 (d_o + 2h)^2}{6250\, S_1\, k\, d_o\, h\, (d_o + h)} \text{ mm (in)}$$

$$f_y = 9400\, S_2 \frac{k}{d_o}\left[1 + \left(\frac{d_o}{d_o + 2h}\right)^2\right] \text{kg/mm}^2$$

$$\left(f_y = 5970\, S_2 \frac{k}{d_o}\left[1 + \left(\frac{d_o}{d_o + 2h}\right)^2\right] \text{ton/in}^2\right)$$

where t = axial thickness of web which is not to be less than $0{,}525 d_r$, in mm (in),

d_r = minimum diameter of crank shaft determined by 203 using $K_1 = 1{,}8$, $K_2 = 7{,}0$, $Z = 1{,}0$ and $T = 44$ kg/mm² (28 ton/in²) for the proposed power rating, in mm (in),

d_o = diameter of hole in crank web, in mm (in),

h = radial thickness of metal around hole in crank web, in mm (in),

S_1 = minimum shrinkage allowance at pins or journals, in mm (in),

S_2 = maximum shrinkage allowance at pins or journals, in mm (in),

k = 1 for solid pins or journals or as determined from Fig. H 2.5 for pins or journals with central holes,

d_i = diameter of holes in pins or journals, in mm (in),

f_y = specified minimum yield stress of the material of the crank web, in kg/mm² (ton/in²).

207 Reference marks are to be provided on the outer junction of the crank webs with the crank pins and journals.

Fillets and Oil Holes

208 Fillets at the junctions of crank webs with crank pins or journals, where these are formed as solid forgings or castings, are to have a smooth finish.

Oil holes at the surfaces of crank pins and journals are to be rounded to an even contour with a smooth finish.

TABLE H 2.1

CRANK SHAFT COEFFICIENTS A AND C FOR 2SCSA ENGINES

No. of Cyls.	Firing Order (Equal Intervals)	Forward Firing		Reverse Firing	
		A	C	A	C
2	1-2	0,41	2,5	0,41	2,5
3	1-2-3	0,38	3,9	0,38	3,9
4	1-2-3-4	0,36	4,5	0,36	4,5
	1-2-4-3	0,36	4,5	0,36	4,5
	1-3-2-4	0,36	4,6	0,36	4,6
5	1-2-4-5-3	0,34	5,4	0,34	5,4
	1-2-5-3-4	0,36	4,9	0,36	4,9
	1-3-5-2-4	0,35	5,0	0,35	5,1
	1-4-3-2-5	0,35	5,0	0,35	5,0
6	1-3-5-2-4-6	0,36	5,0	0,37	4,3
	1-4-2-6-3-5	0,38	3,9	0,38	3,9
	1-4-3-5-2-6	0,38	3,9	0,38	3,9
	1-4-5-2-3-6	0,36	5,0	0,37	4,3
	1-5-3-4-2-6	0,38	3,9	0,38	3,9
7	1-4-6-2-5-3-7	0,38	3,7	0,35	5,4
	1-4-7-2-3-5-6	0,35	5,3	0,35	5,4
	1-5-2-6-4-3-7	0,37	4,4	0,37	4,4
	1-5-3-6-2-4-7	0,38	3,6	0,35	5,4
	1-5-4-6-2-3-7	0,37	4,3	0,35	5,0
	1-6-3-4-5-2-7	0,37	4,4	0,37	4,4
	1-6-3-5-4-2-7	0,37	4,4	0,37	4,4
8	1-5-4-7-2-6-3-8	0,34	5,8	0,34	5,8
	1-5-6-2-7-3-4-8	0,35	5,2	0,35	5,2
	1-5-8-2-4-7-3-6	0,35	5,5	0,35	5,5
	1-6-3-7-2-5-4-8	0,34	5,8	0,34	5,8
	1-6-3-8-2-5-4-7	0,34	5,8	0,34	5,8
	1-6-4-2-7-3-5-8	0,35	5,2	0,35	5,2
	1-6-4-2-8-3-5-7	0,35	5,2	0,35	5,2
	1-6-4-7-2-5-3-8	0,34	5,8	0,34	5,8
	1-6-5-2-7-4-3-8	0,35	5,2	0,35	5,2
	1-6-5-2-8-3-4-7	0,35	5,2	0,35	5,2
	1-7-2-5-4-6-3-8	0,32	6,7	0,32	6,7
	1-7-3-4-6-5-2-8	0,32	6,7	0,32	6,7
	1-7-3-5-4-6-2-8	0,32	6,7	0,32	6,7
	1-7-4-3-6-5-2-8	0,32	6,7	0,32	6,7
9	1-4-9-2-5-7-3-6-8	0,33	6,6	0,33	6,6
	1-4-9-7-2-3-6-8-5	0,35	6,1	0,35	6,1
	1-5-7-3-8-2-6-4-9	0,35	5,1	0,35	5,1
	1-5-9-2-4-7-3-6-8	0,33	6,6	0,33	6,6
	1-6-7-2-5-8-3-4-9	0,33	6,6	0,33	6,6
	1-6-7-3-4-9-2-5-8	0,33	6,6	0,33	6,6
	1-6-7-3-5-8-2-4-9	0,33	6,6	0,33	6,6
	1-6-8-2-5-7-3-4-9	0,33	6,6	0,33	6,6
	1-7-5-3-9-2-6-4-8	0,35	5,1	0,35	5,1
	1-8-3-6-5-4-7-2-9	0,32	6,8	0,32	6,8
10	1-5-9-3-4-8-7-2-6-10	0,31	7,6	0,31	7,6
	1-6-4-9-3-8-2-7-5-10	0,33	6,3	0,33	6,2
	1-6-5-9-2-8-3-7-4-10	0,33	6,3	0,33	6,2
	1-6-9-2-5-10-3-4-7-8	0,31	7,6	0,32	7,4
	1-6-9-2-5-10-4-3-8-7	0,31	7,6	0,32	7,1
	1-6-10-2-4-9-5-3-7-8	0,31	7,6	0,32	7,4
	1-7-3-9-5-6-2-8-4-10	0,33	6,3	0,33	6,3
	1-7-6-3-9-2-8-5-4-10	0,34	5,9	0,32	6,9
	1-7-8-3-4-10-2-6-5-9	0,32	6,7	0,33	6,3
	1-7-9-2-4-10-3-5-6-8	0,32	6,7	0,32	7,4
	1-8-4-7-2-10-3-6-5-9	0,33	6,2	0,33	6,1
	1-8-5-4-9-2-7-6-3-10	0,34	5,9	0,32	6,9
	1-8-5-6-3-10-2-7-4-9	0,33	6,1	0,33	6,2
	1-8-5-7-2-10-3-6-4-9	0,33	6,2	0,33	6,1
	1-9-3-7-5-6-4-8-2-10	0,31	7,6	0,31	7,6
	1-9-4-5-8-3-6-7-2-10	0,31	7,6	0,31	7,6
11	1-9-5-7-3-11-2-8-6-4-10	0,34	6,1	0,34	6,0
	1-9-6-4-10-2-8-5-7-3-11	0,32	7,2	0,31	7,9
	1-10-3-8-6-5-7-4-9-2-11	0,30	8,3	0,30	8,3
12	1-4-8-12-3-5-7-10-2-6-9-11	0,34	5,8	0,32	7,0
	1-5-11-9-2-4-12-7-3-6-10-8	0,32	7,0	0,32	7,1
	1-5-12-7-2-6-10-8-3-4-11-9	0,32	7,0	0,31	8,3
	1-6-8-10-3-5-7-12-2-4-9-11	0,34	5,8	0,32	7,0
	1-6-11-7-3-5-10-9-2-4-12-8	0,32	7,0	0,33	6,5
	1-8-6-10-2-9-4-11-3-5-7-12	0,31	8,3	0,31	8,3
	1-8-6-10-2-9-4-11-3-7-5-12	0,31	8,3	0,31	8,3
	1-9-5-10-3-8-4-12-2-7-6-11	0,31	8,2	0,31	8,3
	1-10-5-7-9-2-12-3-8-6-4-11	0,33	6,8	0,33	6,8

TABLE H 2.2

CRANK SHAFT COEFFICIENTS A AND C FOR 4SCSA ENGINES

No. of Cyls.	Firing Order (Equal Intervals)	Forward Firing		Reverse Firing	
		A	C	A	C
2	1-2	0,43	2,5	0,43	2,5
3	1-2-3	0,41	3,2	0,41	3,2
4	1-2-3-4	0,42	2,8	0,42	2,8
	1-2-4-3	0,42	2,8	0,42	2,8
5	1-2-4-5-3	0,38	4,5	0,38	4,6
	1-4-3-2-5	0,38	4,7	0,38	4,6
6	1-2-3-6-5-4	0,41	3,4	0,41	3,4
	1-2-4-6-3-5	0,40	3,9	0,40	3,9
	1-2-4-6-5-3	0,41	3,4	0,41	3,4
	1-2-5-6-4-3	0,41	3,4	0,41	3,4
	1-4-2-6-3-5	0,40	3,9	0,40	3,9
7	1-2-4-6-7-5-3	0,37	5,0	0,37	5,1
8	1-2-3-5-8-7-6-4	0,38	4,9	0,38	4,9
	1-2-4-6-8-7-5-3	0,38	4,9	0,38	4,9
	1-2-5-6-8-7-4-3	0,38	4,9	0,38	4,9
	1-3-2-4-8-6-7-5	0,39	4,4	0,39	4,4
	1-3-2-5-8-6-7-4	0,39	4,4	0,39	4,4
	1-3-5-2-8-6-4-7	0,37	5,2	0,37	5,2
	1-3-7-4-8-6-2-5	0,38	4,9	0,38	4,8
	1-4-6-2-8-5-3-7	0,37	5,2	0,37	5,2
	1-4-7-3-8-5-2-6	0,37	5,2	0,37	5,2
	1-5-2-6-4-8-3-7	0,39	4,5	0,39	4,5
	1-5-3-2-8-4-6-7	0,37	5,2	0,37	5,2
	1-5-7-3-8-4-2-6	0,37	5,2	0,37	5,2
	1-6-4-2-8-3-5-7	0,37	5,2	0,37	5,2
9	1-2-4-6-8-9-7-5-3	0,37	5,5	0,37	5,5
	1-4-2-3-7-8-6-9-5	0,37	4,9	0,37	5,4
	1-4-7-2-6-9-3-5-8	0,37	5,3	0,37	5,3
	1-5-9-3-6-8-2-4-7	0,37	5,3	0,37	5,3
	1-5-9-3-7-8-2-4-6	0,37	5,3	0,37	5,3
10	1-4-3-2-5-10-7-8-9-6	0,37	5,1	0,37	5,2
	1-4-8-2-5-10-7-3-9-6	0,37	5,4	0,37	5,4
	1-6-2-8-4-10-5-9-3-7	0,37	5,4	0,36	5,4
	1-6-9-3-4-10-5-2-8-7	0,36	5,8	0,35	5,8
12	1-3-8-11-9-7-12-10-5-2-4-6	0,35	6,3	0,35	6,3
	1-9-2-7-4-8-6-10-5-12-3-11	0,37	5,7	0,37	5,7

TABLE H 2.3

CRANK SHAFT COEFFICIENTS A AND C FOR 2SCSA VEE ENGINES

No. of Cyls.	Firing Order per Bank (Equal Intervals)	Firing Interval Between Banks									
		36°		45°		50°		63,5°		90°	
		A	C	A	C	A	C	A	C	A	C
4	1–2	0,64	3,6	0,55	3,7	0,54	3,7	0,53	3,6	0,53	3,8
6	1–2–3	0,61	4,9	0,52	4,9	0,52	5,0	0,50	5,3	0,50	5,7
	1–3–2	0,61	5,0	0,52	5,3	0,51	5,4	0,50	5,4	0,50	5,2
8	1–2–4–3	0,59	6,5	0,49	6,5	0,49	6,6	0,47	6,8	0,43	9,2
	1–3–2–4	0,59	6,0	0,51	5,6	0,50	5,6	0,47	6,8	0,43	9,2
	1–3–4–2	0,59	6,5	0,49	6,5	0,49	6,6	0,47	6,8	0,43	9,2
	1–4–2–3	0,59	5,9	0,51	5,6	0,50	5,6	0,47	6,8	0,43	9,2
10	1–4–3–2–5	0,59	6,1	0,49	6,7	0,47	7,4	0,43	9,4	0,45	8,1
	1–5–2–3–4	0,59	6,2	0,49	6,7	0,47	7,4	0,43	9,4	0,45	8,1
12	1–3–5–2–4–6	0,57	7,4	0,45	9,0	0,43	9,8	0,40	10,6	0,46	7,6
	1–5–3–4–2–6	0,57	7,4	0,45	9,0	0,43	9,8	0,40	10,6	0,46	7,6
	1–6–2–4–3–5	0,57	7,4	0,45	9,0	0,43	9,8	0,40	10,6	0,46	7,6
	1–6–4–2–5–3	0,57	7,4	0,45	9,0	0,43	9,8	0,40	10,6	0,46	7,6
14	1–6–3–4–5–2–7	0,54	9,0	0,43	10,3	0,41	10,7	0,41	10,1	0,41	10,3
	1–7–2–5–4–3–6	0,54	9,0	0,42	10,6	0,40	10,7	0,41	10,4	0,42	9,6
16	1–6–4–7–2–5–3–8	0,56	7,9	0,42	11,2	0,41	11,2	0,42	10,2	0,39	11,4
	1–8–3–5–2–7–4–6	0,56	7,9	0,42	11,2	0,41	11,2	0,42	10,2	0,39	11,4
18	1–6–8–2–5–7–3–4–9	0,51	11,4	0,41	12,0	0,41	11,6	0,41	10,8	0,40	11,9
	1–9–4–3–7–5–2–8–6	0,51	11,4	0,40	12,4	0,40	11,8	0,40	11,5	0,40	11,9
20	1–8–5–7–2–10–3–6–4–9	0,50	12,6	0,41	12,5	0,40	12,4	0,40	12,1	0,40	12,3
	1–9–4–6–3–10–2–7–5–8	0,50	12,6	0,41	12,7	0,40	12,4	0,39	12,4	0,40	12,3

CRANK SHAFT COEFFICIENTS A

MINIMUM FIRING INTERVAL

No. of Cyls.	Firing Order per Bank (Equal Intervals)	40°		45°		50°		60°		80°		90°	
		A	C	A	C	A	C	A	C	A	C	A	C
4		0,67	3,4	0,63	3,5	0,61	3,5	0,59	3,5	0,56	3,7	0,54	3,8
6	ALL	0,65	4,7	0,60	4,8	0,58	4,8	0,56	5,0	0,54	4,6	0,54	4,2
8	ALL	0,67	3,8	0,63	3,9	0,61	3,8	0,58	3,8	0,55	3,9	0,54	4,5
10	1-2-4-5-3	0,60	6,7	0,57	6,5	0,56	6,2	0,54	5,7	0,53	4,9	0,52	5,1
	1-3-5-4-2	0,60	6,8	0,57	6,4	0,55	6,1	0,54	5,6	0,53	4,9	0,52	5,1
12	1-2-4-6-3-5	0,63	5,9	0,58	5,9	0,56	5,9	0,54	5,9	0,51	5,8	0,50	5,7
	1-2-4-6-5-3	0,63	5,4	0,59	5,5	0,57	5,6	0,54	5,7	0,51	5,9	0,52	5,7
	1-2-5-6-4-3	0,63	5,4	0,59	5,5	0,57	5,6	0,54	5,8	0,50	6,1	0,50	6,2
	1-3-4-6-5-2	0,63	5,4	0,59	5,5	0,57	5,6	0,54	5,7	0,51	5,7	0,52	5,7
	1-3-5-6-4-2	0,63	5,4	0,59	5,5	0,57	5,6	0,54	5,9	0,51	5,9	0,50	6,1
	1-4-2-6-3-5	0,64	5,9	0,58	5,9	0,56	5,9	0,54	5,9	0,51	5,8	0,50	5,7
	1-5-3-6-2-4	0,64	5,9	0,58	5,9	0,56	5,9	0,54	5,9	0,53	5,4	0,50	5,9
	1-5-3-6-4-2	0,63	5,9	0,58	5,9	0,56	5,9	0,54	5,9	0,51	5,7	0,52	5,7
14	1-2-4-6-7-5-3	0,61	6,6	0,57	6,5	0,56	6,2	0,52	7,0	0,47	8,3	0,44	[illegible]
	1-3-5-7-6-4-2	0,60	6,6	0,57	6,6	0,56	6,3	0,52	6,5	0,47	8,5	0,45	[illegible]
16	1-2-4-6-8-7-5-3	0,59	7,6	0,55	7,6	0,54	7,5	0,50	7,6	0,45	9,0	0,43	[illegible]
	1-3-2-4-8-6-7-5	0,61	6,7	0,57	6,6	0,56	6,5	0,52	7,1	0,45	9,0	0,43	[illegible]
	1-3-5-2-8-6-4-7	0,59	7,2	0,56	7,0	0,55	6,8	0,52	7,1	0,45	9,0	0,43	[illegible]
	1-3-5-7-8-6-4-2	0,59	7,6	0,55	7,6	0,54	7,5	0,50	8,1	0,45	9,0	0,43	[illegible]
	1-3-7-5-8-6-2-4	0,60	6,9	0,56	6,8	0,55	6,8	0,51	7,2	0,45	9,0	0,43	[illegible]
	1-4-2-6-8-5-7-3	0,60	6,9	0,56	6,8	0,55	6,8	0,52	7,1	0,45	9,0	0,43	[illegible]
	1-4-6-2-8-5-3-7	0,59	7,6	0,59	7,4	0,54	7,2	0,52	7,1	0,45	9,0	0,43	[illegible]
	1-4-7-3-8-5-2-6	0,61	6,7	0,59	7,4	0,54	7,0	0,53	6,5	0,45	9,0	0,43	[illegible]
	1-5-7-3-8-4-2-6	0,59	7,6	0,59	7,4	0,54	7,0	0,52	7,1	0,45	9,0	0,43	[illegible]
	1-5-7-6-8-4-2-3	0,61	6,7	0,57	6,6	0,56	6,5	0,52	7,1	0,45	9,0	0,43	[illegible]
	1-6-2-4-8-3-7-5	0,59	7,6	0,59	7,4	0,54	7,0	0,52	7,1	0,45	9,0	0,43	[illegible]
	1-6-2-5-8-3-7-4	0,59	7,6	0,59	7,4	0,54	7,0	0,53	6,5	0,45	9,0	0,43	[illegible]
	1-6-4-2-8-3-5-7	0,59	7,6	0,59	7,4	0,54	7,0	0,52	7,1	0,45	9,0	0,43	[illegible]
	1-6-4-7-2-5-3-8	0,61	6,7	0,57	6,6	0,56	6,5	0,52	7,1	0,45	9,0	0,43	[illegible]
	1-7-3-5-8-2-6-4	0,59	7,6	0,59	7,4	0,54	7,0	0,52	7,1	0,45	9,0	0,43	[illegible]
	1-7-4-6-8-2-5-3	0,59	7,2	0,59	7,0	0,54	8,1	0,50	7,6	0,45	9,0	0,43	[illegible]
	1-7-5-3-8-2-4-6	0,59	7,6	0,59	7,6	0,54	7,0	0,52	7,1	0,45	9,0	0,43	[illegible]
	1-8-3-5-2-7-4-6	0,61	6,7	0,57	6,6	0,56	6,5	0,52	7,1	0,45	9,0	0,43	[illegible]
18	1-2-4-6-8-9-7-5-3	0,58	8,4	0,54	8,3	0,52	8,4	0,48	9,1	0,42	10,7	0,43	[illegible]
	1-3-5-7-9-8-6-4-2	0,58	8,4	0,54	8,3	0,51	8,6	0,48	8,8	0,42	10,7	0,43	[illegible]
	1-5-9-3-6-8-2-4-7	0,59	7,2	0,56	7,4	0,54	7,6	0,50	8,2	0,43	10,3	0,44	
	1-7-4-2-8-6-3-9-5	0,59	7,1	0,56	7,0	0,54	7,3	0,50	8,2	0,43	10,3	0,44	
20	1-4-3-2-5-10-7-8-9-6	0,59	7,8	0,56	7,9	0,53	8,3	0,48	9,5	0,44	10,2	0,45	
	1-6-3-7-2-10-5-8-4-9	0,59	7,9	0,56	7,9	0,53	8,2	0,48	9,5	0,44	10,2	0,45	
	1-6-9-8-7-10-5-2-3-4	0,58	7,8	0,54	8,1	0,51	8,4	0,48	9,3	0,44	10,2	0,45	
	1-9-4-8-5-10-2-7-3-6	0,58	7,8	0,56	7,9	0,53	8,3	0,48	9,3	0,44	10,2	0,45	

ND C FOR 4SCSA VEE ENGINES

BETWEEN BANKS												Firing Order per Bank (Equal Intervals)	No. of Cyls.
270°		280°		300°		310°		315°		320°			
A	C	A	C	A	C	A	C	A	C	A	C		
0,48	4,0	0,48	4,0	0,47	3,8	0,46	3,9	0,45	4,0	0,45	4,1		4
0,48	5,8	0,45	5,4	0,43	5,7	0,41	5,6	0,42	5,7	0,42	5,5	ALL	6
0,47	4,8	0,47	4,9	0,45	4,8	0,45	4,6	0,45	4,5	0,45	4,1	ALL	8
0,39	8,4	0,37	9,4	0,37	9,1	0,37	8,3	0,38	7,5	0,38	7,5	1-2-4-5-3	10
0,39	8,4	0,37	9,4	0,37	9,0	0,36	8,2	0,38	7,8	0,38	7,4	1-3-5-4-2	
0,44	6,0	0,43	6,1	0,41	6,6	0,41	6,7	0,40	6,7	0,40	6,5	1-2-4-6-3-5	12
0,46	5,9	0,45	5,7	0,43	5,9	0,41	6,1	0,41	6,1	0,41	6,0	1-2-4-6-5-3	
0,45	5,7	0,45	5,7	0,43	5,9	0,41	6,1	0,41	6,1	0,41	6,0	1-2-5-6-4-3	
0,46	5,9	0,44	5,9	0,43	5,9	0,41	6,1	0,41	6,1	0,41	6,0	1-3-4-6-5-2	
0,45	5,7	0,45	5,7	0,43	5,9	0,41	6,1	0,41	6,1	0,41	6,0	1-3-5-6-4-2	
0,43	6,3	0,43	6,1	0,41	6,6	0,41	6,7	0,40	6,7	0,40	6,5	1-4-2-6-3-5	
0,44	6,1	0,43	6,1	0,41	6,6	0,41	6,7	0,40	6,7	0,40	6,5	1-5-3-6-2-4	
0,44	6,1	0,43	6,1	0,41	6,6	0,41	6,7	0,40	6,7	0,40	6,5	1-5-3-6-4-2	
0,43	6,8	0,41	7,8	0,35	10,2	0,33	10,7	0,33	10,6	0,33	10,1	1-2-4-6-7-5-3	14
0,43	6,6	0,41	7,6	0,35	10,1	0,33	10,9	0,33	10,5	0,33	10,1	1-3-5-7-6-4-2	
0,36	10,3	0,38	9,4	0,40	7,6	0,40	7,1	0,39	7,3	0,39	6,8	1-2-4-6-8-7-5-3	16
0,36	10,3	0,37	9,5	0,41	7,4	0,41	6,8	0,41	6,5	0,41	6,3	1-3-2-4-8-6-7-5	
0,34	11,4	0,36	10,6	0,37	8,7	0,38	8,1	0,37	7,9	0,38	7,8	1-3-5-2-8-6-4-7	
0,36	10,3	0,38	9,4	0,40	7,6	0,40	7,1	0,39	7,3	0,39	7,4	1-3-5-7-8-6-4-2	
0,36	10,3	0,38	9,4	0,40	7,6	0,40	7,1	0,39	7,0	0,39	7,0	1-3-7-5-8-6-2-4	
0,36	10,3	0,37	9,5	0,40	7,3	0,40	6,9	0,40	6,8	0,40	6,6	1-4-2-6-8-5-7-3	
0,34	11,4	0,36	10,6	0,37	8,7	0,38	8,1	0,38	7,9	0,38	7,8	1-4-6-2-8-5-3-7	
0,36	10,3	0,37	9,4	0,39	8,1	0,39	7,5	0,39	7,3	0,39	7,2	1-4-7-3-8-5-2-6	
0,36	10,3	0,37	9,4	0,39	8,1	0,39	7,5	0,39	7,3	0,39	7,2	1-5-7-3-8-4-2-6	
0,36	10,3	0,38	9,4	0,41	7,4	0,41	6,8	0,41	6,5	0,41	6,3	1-5-7-6-8-4-2-3	
0,36	10,3	0,37	9,4	0,39	8,1	0,39	7,5	0,39	7,3	0,39	7,2	1-6-2-4-8-3-7-5	
0,36	10,3	0,37	9,4	0,39	8,1	0,39	7,5	0,39	7,3	0,39	7,2	1-6-2-5-8-3-7-4	
0,33	11,6	0,35	11,9	0,37	9,1	0,38	8,1	0,37	8,1	0,37	7,9	1-6-4-2-8-3-5-7	
0,36	10,3	0,38	9,4	0,41	7,4	0,41	6,8	0,40	6,9	0,39	7,2	1-6-4-7-2-5-3-8	
0,33	11,6	0,35	11,9	0,37	9,1	0,38	8,3	0,37	8,1	0,37	7,9	1-7-3-5-8-2-6-4	
0,34	11,4	0,41	12,1	0,37	8,7	0,38	8,1	0,37	7,9	0,38	7,8	1-7-4-6-8-2-5-3	
0,34	11,4	0,36	10,6	0,37	8,7	0,38	8,1	0,37	7,9	0,38	7,8	1-7-5-3-8-2-4-6	
0,36	10,3	0,38	9,4	0,41	7,4	0,41	6,8	0,40	6,9	0,39	7,2	1-8-3-5-2-7-4-6	
0,42	7,8	0,42	7,7	0,38	9,1	0,35	10,2	0,33	10,9	0,32	11,2	1-2-4-6-8-9-7-5-3	18
0,42	7,6	0,42	7,5	0,38	9,1	0,35	10,2	0,33	10,9	0,32	11,2	1-3-5-7-9-8-6-4-2	
0,39	8,8	0,41	8,1	0,39	8,6	0,36	9,9	0,34	10,5	0,33	10,7	1-5-9-3-6-8-2-4-7	
0,39	8,8	0,41	8,1	0,39	8,6	0,36	9,9	0,34	10,5	0,33	10,7	1-7-4-2-8-6-3-9-5	
0,40	9,1	0,37	10,3	0,36	10,1	0,37	9,1	0,37	8,7	0,37	8,3	1-4-3-2-5-10-7-8-9-6	20
0,36	11,0	0,33	12,0	0,33	11,4	0,35	10,2	0,35	9,7	0,36	9,1	1-6-3-7-2-10-5-8-4-9	
0,40	9,1	0,37	10,3	0,36	10,1	0,37	9,1	0,37	8,7	0,37	8,3	1-6-9-8-7-10-5-2-3-4	
0,36	11,0	0,33	12,0	0,33	11,4	0,35	10,2	0,35	9,7	0,36	9,1	1-9-4-8-5-10-2-7-3-6	

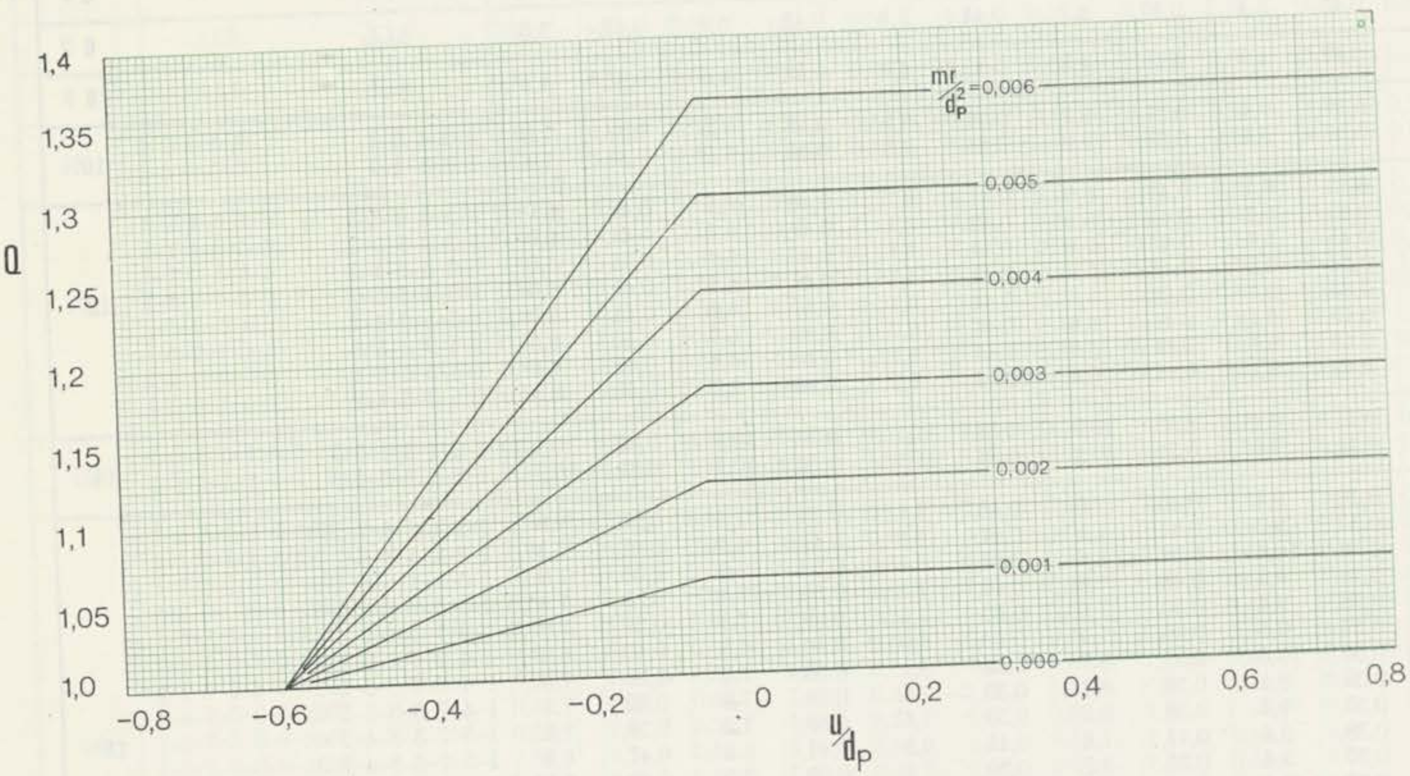


FIG. H 2.1

Fig. H 2.1

Fig. H 2.2

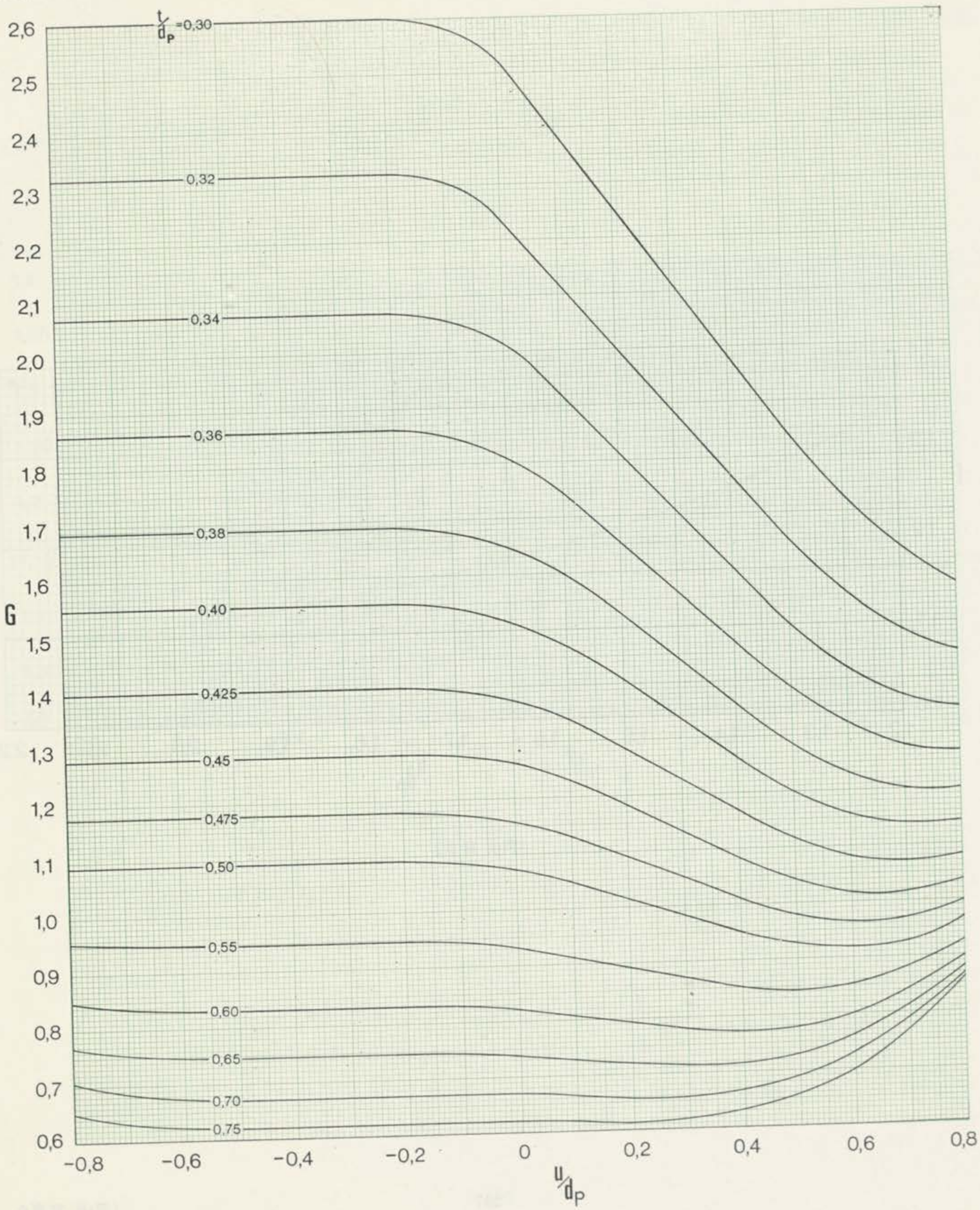


FIG. H 2.3

Fig. H 2.3

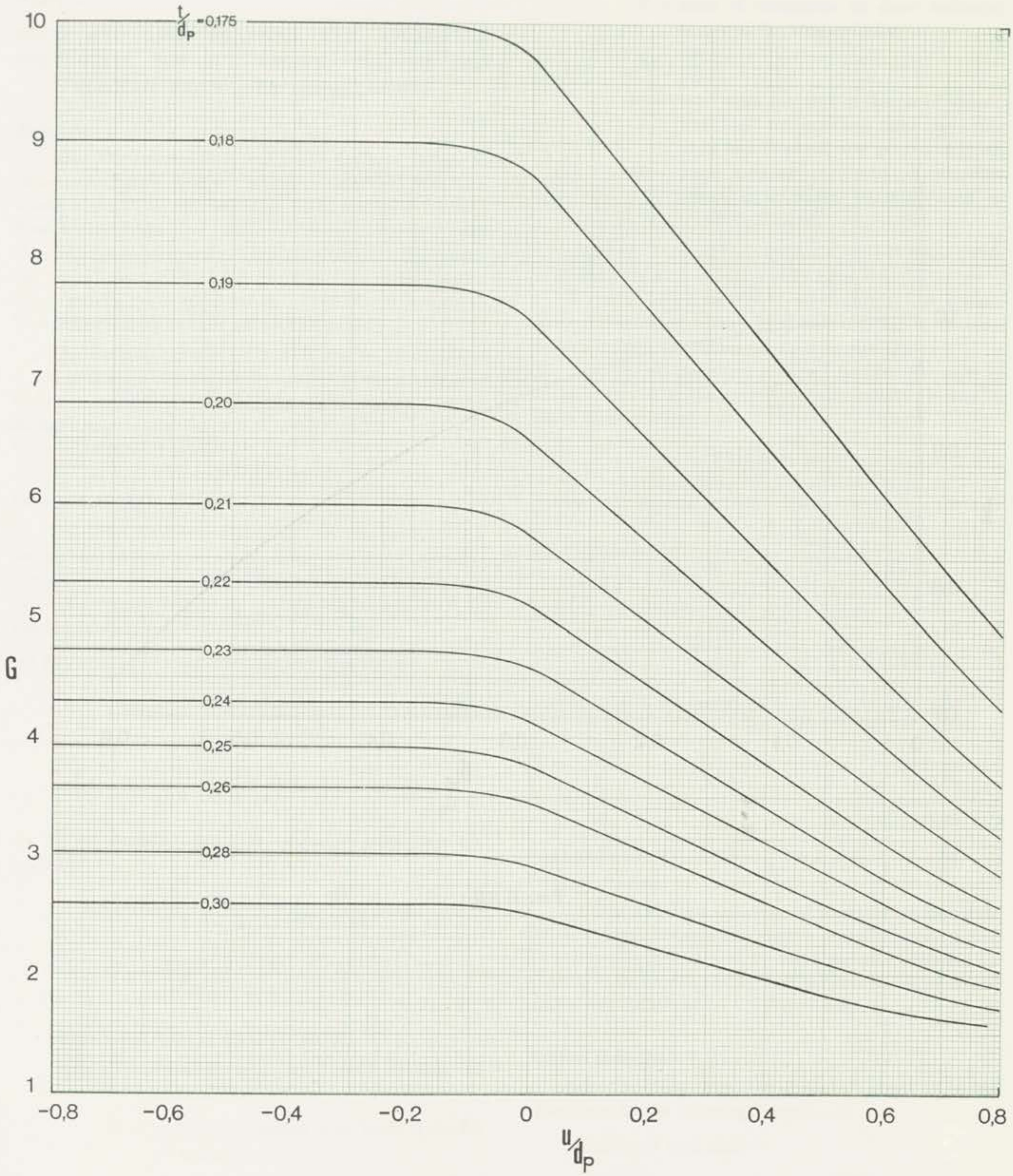

t/dp = 0,175
0,18
0,19
0,20
0,21
0,22
0,23
0,24
0,25
0,26
0,28
0,30
G
10
9
8
7
6
5
4
3
2
1
−0,8
−0,6
−0,4
−0,2
0
0,2
0,4
0,6
0,8
u/dp

Fig. H 2.4

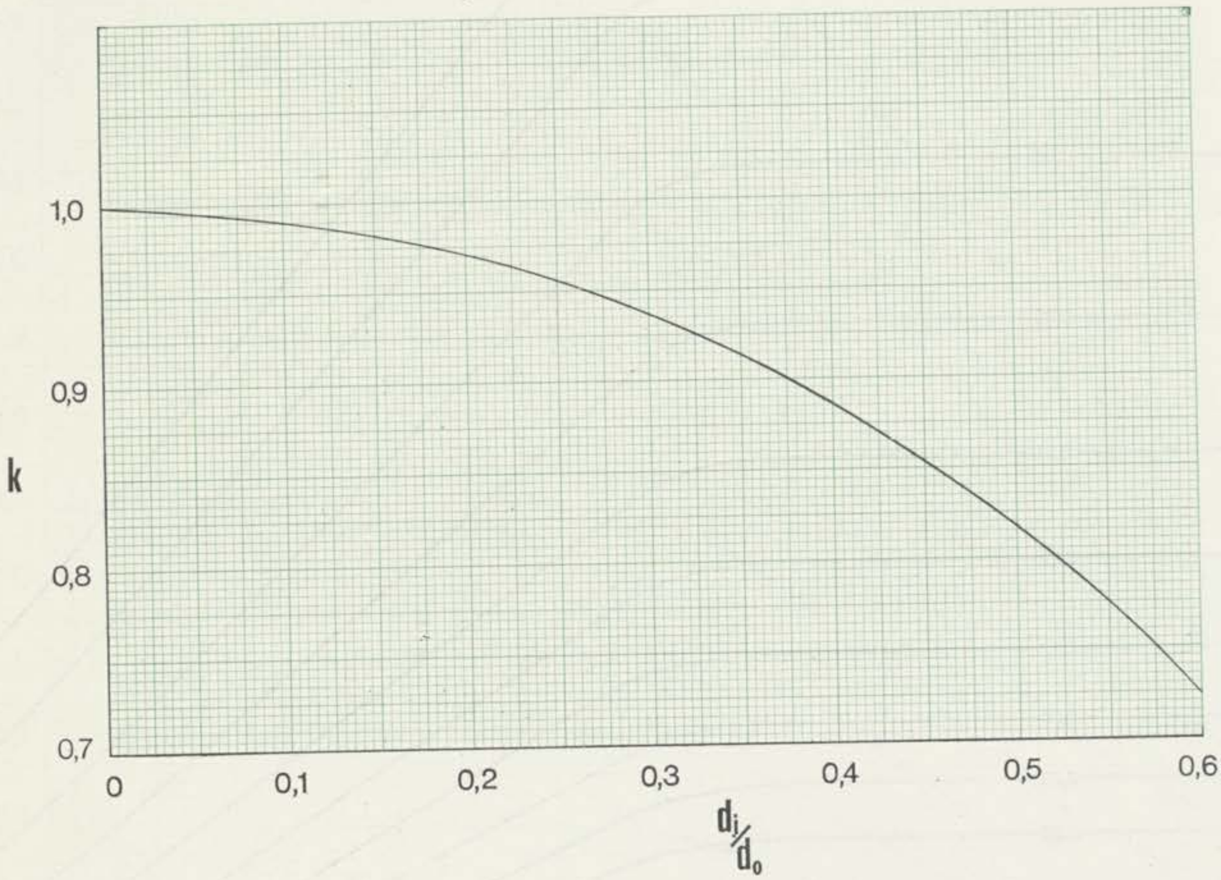


FIG. H 2.5

PART 2

GEAR AND LINE SHAFTING AND ASSOCIATED COMPONENTS FOR OIL ENGINE, TURBINE AND ELECTRIC PROPULSION INSTALLATIONS

Materials

221 The intermediate and other shafts of carbon or carbon-manganese steel are to have a specified minimum tensile strength of not less than 44 kg/mm² (28 ton/in²). Steel having a specified minimum tensile strength greater than 44 kg/mm² (28 ton/in²) but not exceeding 80 kg/mm² (50 ton/in²) may be used but screw shafts and tube shafts are, in general, to be restricted to a range of tensile strength between 44 and 52 kg/mm² (28 and 33 ton/in²).

The material is to comply with the requirements of Q 602 to Q 610 and where it is proposed to use a carbon or carbon-manganese steel having a specified minimum tensile strength greater than 60 kg/mm² (38 ton/in²) full details are to be submitted for consideration.

Intermediate Shaft

222 The diameter of the intermediate shaft d if of carbon or carbon-manganese steel, having a specified minimum tensile strength not less than 44 kg/mm² (28 ton/in²) but not exceeding 80 kg/mm² (50 ton/in²), is not to be less than determined by the following formulæ:—

Oil Engines, turbine and electric propelling motors

$$d = 25{,}4\ C\ \sqrt[3]{\frac{H}{R}\left(\frac{60}{T+16}\right)}\ \text{mm} \qquad (1)$$

$$\left(d = C\ \sqrt[3]{\frac{H}{R}\left(\frac{38}{T+10}\right)}\ \text{in}\right)$$

or, for oil engines where the necessary particulars are available

$$d = 89\ \sqrt[3]{\frac{H}{R}\left(\frac{X+A}{1+A}\right)\left(\frac{60}{T+16}\right)}\ \text{mm} \qquad (2)$$

$$\left(d = 3{\cdot}5\ \sqrt[3]{\frac{H}{R}\left(\frac{X+A}{1+A}\right)\left(\frac{38}{T+10}\right)}\ \text{in}\right)$$

where H and R are as defined in H 105,

T = specified minimum tensile strength, in kg/mm² (ton/in²),

C = coefficient obtained from Table H 2.5 for oil engines,

= 3·5 for turbines and electric propelling motors,

X = ratio of maximum to mean indicated torque at the after cylinder,

$A = \dfrac{Je}{Jp}$

Je = total mass moment of inertia of engine, including reciprocating and revolving parts and flywheel, also gearing if fitted,

Jp = mass moment of inertia of propeller including entrained water referred to crank shaft speed.

NOTE 1.—Formula (1) is applicable only to single piston in-line engines with approximately equal firing intervals.

NOTE 2.—Formula (2) is applicable to all engines without restriction of any kind and may allow, in some cases, a smaller shaft diameter than formula (1).

NOTE 3.—Where a percentage figure for the mass of water entrained by the propeller is not available, it may be taken as 25 per cent.

TABLE H 2.5

4 STROKE SINGLE ACTING		2 STROKE SINGLE ACTING	
Number of Cylinders	C	Number of Cylinders	C
1 to 4	4,30	1 or 2	4,50
5	4,15	3	4,20
6	4,05	4	4,00
7	4,00	5	3,90
8	3,90	6	3,80
9	3,85	7	3,75
10	3,70	8	3,65
11 and over	3,55	9 & over	3,55

NOTE.—The Rule diameter of the intermediate shaft for oil engines, turbines and electric propelling motors may be reduced by 3,5 per cent for ships classed exclusively for smooth water service and by 1,75 per cent for ships classed exclusively for service on the Great Lakes.

Turbine Quill Shaft

223 The diameter of the quill shaft is not to be less than given by the following formula:—

Diameter of quill shaft =

$$89\ \sqrt[3]{\frac{H\ 44}{R\ T}}\ \text{mm} \qquad \left(3{\cdot}5\ \sqrt[3]{\frac{H\ 28}{R\ T}}\ \text{in}\right)$$

where H and R are as defined in H 105,

$T =$ specified minimum tensile strength of the material in kg/mm^2 (ton/in^2), which is not to be less than 44 kg/mm^2 (28 ton/in^2).

Final Gear Wheel Shaft

224 Where there is only one pinion geared into the final wheel, or where there are two pinions which are set to subtend an angle at the centre of the shaft of less than 120 degrees, the diameter of the shaft at the final wheel and the adjacent journals is not to be less than 1,16 times that required for the intermediate shaft

Where there are two pinions geared into the final wheel opposite, or nearly opposite, to each other, the diameter of the shaft at the final wheel and the adjacent journals is not to be less than 1,1 times that required for the intermediate shaft.

In both the above cases, abaft the journals the shaft may be gradually tapered down to the diameter required for an intermediate shaft determined according to the appropriate formula in 222, where T is to be taken as the specified minimum tensile strength of the final wheel shaft material, in kg/mm^2 (ton/in^2).

Thrust Shaft

225 The diameter at the collars of the thrust shaft transmitting torque is not to be less than 1,15 times that required for the intermediate shaft; outside the collars the diameter may be tapered down to that required for the intermediate shaft. In determining the diameter of the intermediate shaft in accordance with the appropriate formula in 222, T is to be taken as the specified minimum tensile strength of the thrust shaft material, in kg/mm^2 (ton/in^2).

Tube Shaft

226 The diameter of the tube shaft (i.e. the shaft which passes through the stern tube, but does not carry the propeller) is not to be less than 1,14 times that required for the intermediate shaft, and any part of the shaft within or without the tube which may be exposed to sea water is not to be less than 1,17 times that required for the intermediate shaft. The diameter of the intermediate shaft is to be determined in accordance with the appropriate formula in 222 and is to be based on material having a specified minimum tensile strength of 44 kg/mm^2 (28 ton/in^2).

Screw Shaft

227 The diameter of the screw shaft carrying the propeller is not to be less than given by the following formula:—

$$\text{Diameter of screw shaft, in mm (in)} = 1{,}14d + \frac{P}{C}$$

where $d =$ diameter required for the intermediate shaft determined in accordance with the appropriate formula in 222, based on material having a specified minimum tensile strength of 44 kg/mm^2 (28 ton/in^2), in mm (in). For limitations on the mechanical properties of screw shaft material, *see* Q 606,

$P =$ diameter of the propeller, in mm (in),

$C =$ 144 when the shaft is fitted with a continuous liner or is oil lubricated and provided with an approved type of oil sealing gland,

$=$ 100 for other shafts.

Screw shafts which run in stern tubes may have the end forward of the stern gland tapered down to a diameter, at the coupling flange, of 1,14 times that required for the intermediate shaft. Abrupt changes in shaft section at the screw shaft to intermediate shaft couplings should be avoided.

Hollow Shafts

228 Where the thrust, intermediate, tube and screw shafts have central holes, the diameters of the shafts as determined by the foregoing formulæ need not be increased, provided the diameter of the central hole in a shaft does not exceed one-third of the shaft diameter.

Couplings

229 The thicknesses of the coupling flanges at the pitch circle of the bolt holes are not to be less than the diameters of the coupling bolts at the face of the couplings as required by 230, and for this purpose the minimum tensile strength of the bolts is to be taken as equivalent to that of the shafts. In the case of the thrust shaft/crank shaft coupling the dimensions of the coupling bolts and flange thickness are to be governed by the crank shaft requirements. The thickness of the screw shaft coupling flange is not to be less than 0,27 of the diameter required for the intermediate shaft, as determined by the appropriate formula in 222, based on material having a specified minimum tensile strength of 44 kg/mm^2 (28 ton/in^2), in mm (in).

The fillet radius at the base of the coupling flange is not to be less than 0,08 of the diameter of the shaft at the coupling, but in the case of crank shafts, the fillet radius at the centre coupling flanges may be 0,05 of the diameter of the shaft at the coupling. The fillets are to have a smooth finish and should not be recessed in way of nuts and bolt heads.

All couplings which are attached to shafts are to be of approved dimensions.

Where couplings are separate from the shafts, provision is to be made to resist the astern pull.

Where a coupling is shrunk on the parallel portion of a shaft or is mounted on a slight taper, for example by means of the oil pressure injection method, full particulars of the coupling including the interference fit should be submitted for special consideration.

See paragraph 108, Chapter R(E)—Guidance Notes on Torsional Vibration Characteristics of Main and Auxiliary Oil Engines.

Coupling Bolts

230 The diameter of the bolts at the joining faces of the couplings is not to be less than that given by the following formula:—

$$\text{Diameter of coupling bolts} = C\sqrt{\frac{d^3 Z}{nr}\left(\frac{T_s + 16}{T_b}\right)}\ \text{mm}$$

$$\left(C\sqrt{\frac{d^3 Z}{nr}\left(\frac{T_s + 10}{T_b}\right)}\ \text{in}\right)$$

where n = number of bolts in the coupling,
r = radius of pitch circle of bolts, in mm (in),
T_b = specified minimum tensile strength of bolts, in kg/mm² (ton/in²).

For coupling bolts for thrust, intermediate, tube and screw shafts,

$C = 0{,}51$,
d = diameter of intermediate shaft determined by the appropriate formula in 222, in mm (in),
$Z = 1{,}0$,
T_s = specified minimum tensile strength of intermediate shaft, in kg/mm² (ton/in²).

For coupling bolts for crank shafts,

$C = 0{,}43$,
d = minimum diameter of crank shaft as calculated from 203 for the proposed power rating (*see* H 105), in mm (in),
Z = appropriate value from 203,
T_s = specified minimum tensile strength of crank shaft, in kg/mm² (ton/in²).

Bronze or Gunmetal Liners on Shafts

231 The thickness of liners fitted on screw shafts or on tube shafts, in way of the bushes, is not to be less, when new, than that given by the following formula:—

$$t = \frac{D + 230}{32}\ \text{mm} \quad \left(t = \frac{D + 9}{32}\ \text{in}\right)$$

where t = thickness of the liner, in mm (in),
D = diameter of the screw or tube shaft under the liner, in mm (in).

The thickness of a continuous liner between the bushes is not to be less than 0,75 t.

232 Continuous liners should preferably be cast in one piece.

Where, however, liners consist of two or more lengths, these are to be butt welded together. In general, the lead content of the gunmetal of each length forming a butt welded liner is not to exceed 0,5 per cent. The composition of the electrodes or filler rods is to be substantially lead-free.

The circumferential butt welds are to be of multi-run, full penetration type. Provision is to be made for contraction of the weld by arranging for a suitable length of the liner containing the weld, if possible about three times the shaft diameter, to be free of the shaft. To prevent damage to the surface of the shaft during welding, a strip of asbestos or other heat resisting material covered by a copper strip should be inserted between the shaft and liner in way of the joint. Other methods for welding this joint may be accepted if approved. The welding is to be carried out by an approved method and to the Surveyors' satisfaction.

Each continuous liner or length of liner is to be tested by hydraulic pressure to 2 kg/cm² (30 lb/in²) after rough machining.

Liners are to be carefully shrunk on, or forced on to the shafts by hydraulic pressure. Pins are not to be used to secure the liners.

233 Effective means are to be provided for preventing water from having access to the shaft at the part between the after end of the liner and the propeller boss.

Propeller Boss, Keys and Keyways

234 The propeller boss is to be a good fit on the screw shaft cone. The length of the forward fitting surface should be about one diameter. The forward edge of the bore of the propeller boss is to be rounded to about a 6 mm (0·25 in) radius.

235 Round ended or sled-runner ended type keys are to be used and the keyways in the propeller boss and cone of the screw shaft are to be provided with a smooth fillet at the bottom of the keyways. The radius of the fillet is to be at least 0,0125 of the diameter of the screw shaft at the top of the cone. The sharp edges at the top of the keyway are to be removed.

Two screwed pins should be provided for securing the key in the keyway and the forward pin should be placed at least one third of the length of the key from the end. The depth of the tapped holes for the screwed pins should not exceed the pin diameter, and the edges of the holes should be slightly bevelled.

The distance between the top of the cone and the forward end of the keyway is not to be less than 0,2 of the diameter of the screw shaft at the top of the cone.

The effective sectional area of the key in shear, in mm^2 (in^2), is not to be less than $\frac{d^3}{2,5d_1}$

where d = diameter required for the intermediate shaft determined in accordance with the appropriate formula in 222 based on material having a specified minimum tensile strength of 44 kg/mm^2 (28 ton/in^2), in mm (in),

d_1 = diameter of shaft at mid-length of the key, in mm (in).

Stern Bush

236 The length of the bearing in the stern bush next to and supporting the propeller is to be as follows:—

(*a*) For water-lubricated bearings which are lined with lignum vitae, rubber composition or approved plastic material, the length is not to be less than four times the diameter required for the screw shaft under the liner.

Forced water lubrication is to be provided for all bearings lined with rubber or plastic and for those bearings lined with lignum vitae where the shaft diameter is 380 mm (15 in) or over. The supply of water may come from a circulating pump or other pressure source. Flow indicators are to be provided for the water service to plastic and rubber bearings. The water grooves in the bearings should be of ample section and of a shape which will be little affected by weardown, particularly for bearings of the plastic type.

The shut-off valve or cock controlling the supply of water is to be fitted direct to the after peak bulkhead or to the stern tube where the water supply enters the stern tube forward of the bulkhead.

(*b*) For bearings which are white metal lined, oil lubricated and provided with an approved type of oil sealing gland, the length of the bearing is to be such that the nominal bearing pressure resulting from the weight of propeller and shaft will not exceed 6,3 kg/cm^2 (90 lb/in^2). In no case is the length of the bearing to be less than twice the diameter required for the screw shaft. The weight of the propeller and of screw shaft, and the type of oil sealing gland are to be stated when the plans are submitted for approval.

(*c*) For bearings of cast iron and bronze which are oil lubricated and fitted with an approved oil gland, the length of the bearing is, in general, not to be less than 4 times the diameter required for the screw shaft.

(*d*) For bearings which are grease lubricated the length of the bearing is not to be less than 4 times the diameter required for the screw shaft.

Oil sealing glands fitted in ships classed for unrestricted service must be capable of accommodating the effects of differential expansion between hull and line of shafting in sea temperatures ranging from Arctic to Tropical. This requirement applies particularly to those glands which span the gap and maintain oil tightness between the sterntube and the propeller boss.

Where a tank supplying lubricating oil to the stern bush is fitted it is to be located above the load water line and is to be provided with a low level alarm device in the engine room.

Where stern bush bearings are oil lubricated, provision should be made for cooling the oil by maintaining water in the after peak tank above the level of the stern tube or by other approved means. Means for ascertaining the temperature of the oil in the stern tube should also be provided.

NOTE.—Where there is compliance with the terms of (*b*) and (*c*) to the Surveyors' satisfaction a screw shaft will be assigned the notation O.G. in the supplement to the Register Book for periodical survey purposes (*see* C 1101).

Screw shafts which are grease lubricated are not eligible for the O.G. notation.

PART 3

TORSIONAL VIBRATIONS

General

241 In addition to the shafting complying with the requirements of Parts 1 and 2 of this Section, where applicable, approval is also dependent on the torsional vibration characteristics of the complete shafting system(s) being found satisfactory.

Calculations of the torsional vibration characteristics of the shafting system(s) are to be prepared and submitted for consideration. Unless the responsibility for preparing and submitting this information is specifically advised, it is the responsibility of the Shipbuilder as main contractor to ensure, in co-operation with the Engine Builders, that this information is prepared and submitted.

Oil Engines

242 The relevant recommendations of Chapter R(E)—Guidance Notes on Torsional Vibration Characteristics of Main and Auxiliary Oil Engines, Section 1, should be adopted and torsional vibration calculations for the following shafting systems are to be submitted for consideration together with the associated plans, also the particulars as detailed in Table R(E) 2.1a of Section 2 of the above Guidance Notes.

(1) Main oil engine propulsion systems, except in the case of ships classed for smooth water service when fitted with engines having powers less than 150 bhp.

(2) Auxiliary oil engine machinery systems used for essential services, where the power developed by the auxiliary engines is 150 bhp or 100kW and over.

In the case of the systems referred to in (1) and (2), where critical speeds are found by calculation to show stresses approaching the limits given in Section 1 of Chapter R(E) within the range of working speeds, torsiograph records may require to be taken from the machinery for the purpose of verifying the calculations. Restricted speed ranges may be imposed on continuous running at speeds where the stresses, or the vibration torques as indicated by tooth separation and gear hammer, are considered to be excessive.

Where changes are subsequently made to a dynamic system which has been approved, e.g. by fitting a propeller of different design to the working propeller or a flexible coupling, revised torsional vibration calculations are to be submitted for consideration.

Attention is drawn to Section 2 of Chapter R(E) for the recommended method of calculation and form of submission.

Turbines and Electric Propelling Motors

243 With turbines or electric motors geared to the shafting and situated aft, calculations of the torsional vibration characteristics for the dynamic system formed by the turbine, motor, gearing, line shafting and propeller are to be submitted for consideration, together with plans of all shafting and propeller and details of power developed by individual turbines throughout the speed range.

Where changes are subsequently made to a dynamic system which has been approved, e.g. by fitting a propeller of different design to the working propeller, revised torsional vibration calculations are to be submitted for consideration.

Where serious critical speeds are found by calculation to occur within the range of working speeds torsiograph records may require to be taken from the machinery for the purpose of verifying the calculations.

Restricted speed ranges may be imposed on continuous running at speeds where the vibration torques, as indicated by tooth separation and gear hammer, are considered to be excessive.

Section 3

REDUCTION GEARING FOR PROPELLING AND AUXILIARY ENGINES

General

301 The following requirements, except where otherwise stated, are applicable to reduction gearing for main propelling purposes and for driving electric generators where the transmitted powers exceed 300 shp and 150 shp for propulsion and auxiliary drives respectively. In any mesh, the terms pinion and wheel refer to the smaller and larger gear respectively. Epicyclic and bevel gears will be specially considered.

302 Particulars of the gearing are to be submitted with the plans for all propulsion gears and for auxiliary gears where the transmitted power exceeds 150 shp, as follows:—

Material specifications,
Shaft horse power and revolutions for each pinion,
Number of teeth in each gear,
Pitch circle diameters,
Helix angles,
Normal pitches of teeth,
Addenda,
Dedenda,
Face widths,

Pressure angles of teeth (normal or transverse),
Minimum backlash,
Centre distance.

Materials

303 The materials for pinions, pinion sleeves, wheel rims, flexible couplings and quill shafts are to be of approved composition and mechanical properties and are to comply with the requirements of Chapter Q. Manufacturer's certificates of test for materials may be accepted in cases where the transmitted power of gears is less than 150 shp.

In the selection of materials for pinions and wheels consideration is to be given to their compatibility in operation. In general, for gears of through-hardened steels, except in the case of low reduction ratios, provision is also to be made for a hardness differential between pinion teeth and wheel teeth for which purposes the specified minimum tensile strength of the wheel rim material is not to be more than 85 per cent of that of the pinion.

DESIGN

Tooth Form

304 The tooth profile in the transverse section is to be of involute shape and the roots of the teeth are to be formed with smooth fillets of radii not less than 12 per cent of the normal pitch.

For propulsion gears the ends of the pinion and wheel teeth are to be cut back from the root at an angle of 45° to 60° to the pitch line in all cases where the ratio F/d exceeds 1,5.

where F = total axial length over pinion helices, less the gap, in mm (in),

d = pitch circle diameter of pinion, in mm (in).

The teeth of pinions and wheels of turbine gears are to be suitably tip-relieved in cases where any of the following conditions apply:—

(i) Normal pitch of teeth exceeds the equivalent of 6,35 mm module (4 D.P. or 0·7854 in).

(ii) Addendum of pinion teeth exceeds 65 per cent of total working depth of engagement.

(iii) Ratio of total working depth of engagement to normal pitch of teeth exceeds 0,75.

All sharp edges left on the tips and ends of pinion and wheel teeth after hobbing or finishing are to be removed.

Deflection of Pinions

305 In order to limit tooth opening arising from loaded deflections, the total axial length, in mm (in), over the gear face, less gap where applicable, is not to exceed

$$c\,d$$

where d = pitch circle diameter of pinion, in mm (in),

c = factor to be determined as follows:—

A = helical angle in degrees.

(a) double-helical pinion meshing with one wheel

$$c = \frac{105 + A}{60}$$

(b) double-helical pinion meshing with two wheels diametrically opposed

$$c = \frac{80 + A}{40}$$

(c) single-helical pinion meshing with one or two wheels

$$c = \frac{75 + A}{60}$$

For spur gears the ratio, face width/diameter, is not to exceed 1,25.

Alternatively, manufacturers may present deflection calculations with details of any intended measures to improve load distribution.

Tooth Loading for Surface Stress

306 In order to limit the tooth surface stress, the tooth load for the proposed power rating (*see* H 105) is not to exceed that given by the following formula:—

$$W = K\,d\,\frac{G}{(G + 1)}$$

where W = maximum permissible tangential tooth load, in kg/cm (lb/in), of overall face width, less gap where applicable.

K = loading factor derived as follows:—

(a) For Turbine Gearing

$$K = \left(\frac{5850 + d\,N}{1\,600\,000}\right) S\,B$$

$$\left(K = \left(\frac{230 + d\,N}{280}\right) S\,B \quad \text{British}\right)$$

(b) For Oil Engine Gearing

$$K = \left(\frac{2300 - d\,N}{170\,000}\right) S\,B$$

$$\left(K = \left(\frac{90 - d\,N}{30}\right) S\,B \quad \text{British}\right)$$

where d = pitch circle diameter of pinion, in mm (in),

N = revolutions per minute of pinion, divided by 1000,

S = value according to Table H 3.1,

S_1 = specified minimum tensile strength of pinion material, in kg/mm^2 (ton/in^2),

S_2 = specified minimum tensile strength of wheel material, in kg/mm^2 (ton/in^2),

F = total axial length over the gear face, less gap, in mm (in),

H = F for single helical and spur gears, or $F/2$ for double helical gears,

p_a = axial pitch of teeth, in mm (in),

G = gear ratio = $\dfrac{\text{pinion speed}}{\text{wheel speed}}$

$B = 1$, if $H \geqslant 1{,}15\ p_a$,

$= 0{,}6$, if $H < 1{,}15\ p_a$.

For divided power transmission where a pinion meshes with two or more wheels or a wheel meshes with two or more pinions, the value of S determined for that gear is to be reduced by 12 per cent.

The permissible loading may be increased by 10 per cent in single reduction gearing for main propelling purposes and in double reduction gearing where it is proposed to connect the primary and secondary gears of single helical gears or spurs, by means of a quill shaft, or approved equivalent, also for double helical gears where, in addition to a quill shaft, provision is made for either:—

(i) a coupling providing axial articulation, or

(ii) (a) both helices of the main wheel are finish hobbed in the same direction of rotation and at the same setting of the blank on the hobber table;

or alternatively,

(b) the matching of the cumulative pitch errors on the two helices can be shown to be within acceptable limits.

Where single reduction gearing is used for auxiliary drives, the permissible loading may be increased by 15 per cent.

Where the teeth of gears made of through-hardened steels are finished by an approved post-hobbing process, or profile ground, or where it can be demonstrated in advance that the finish and profile of the teeth are equivalent, the permissible loading, resulting from the product of any allowance factors, may be increased by up to 25 per cent.

Tooth Loading for Bending Stress

307 In order to limit the bending stress at the root section of gear teeth for the proposed power rating (*see* H 105), the fillet radius should be blended smoothly into the involute profile and the normal pitch of the teeth should not be less than that given by the following formula—

$$p_n = \frac{J\,C\,W_1}{(110-A)\,U}$$

where p_n = normal pitch of the teeth, in mm (in),

W_1 = maximum proposed tangential tooth load, in kg/cm (lb/in), of overall face width, less gap where applicable,

F = total axial length over the gear face, less gap, in mm (in).

H = F for single helical and spur gears or $F/2$ for double helical gears,

p_a = axial pitch of the teeth, in mm (in),

$J = 1$, if $H \geqslant p_a$,

$= 0{,}4\ (3{,}5 - H/p_a)$ if $H < p_a$,

$C = \dfrac{1700 + N}{1200}$, if $N \leqslant 1000$,

$= \dfrac{18\,000 + N}{8400}$, if $N > 1000$,

A = helical angle, in degrees.

For the pinion or wheel under consideration:—

N = revolutions per minute,

UTS = specified minimum tensile strength (of core material for surface-hardened steels), in kg/mm^2 (ton/in^2),

$U = \dfrac{UTS + 95}{450}$ $\left(U = \dfrac{UTS + 60}{2}\ \text{British}\right)$

if gear is through-hardened,

$= 0{,}56$ (80 British) if gear is induction-hardened and ground, or nitrided after post-hobbing by an approved process,

$= 0{,}60$ (85 British) if gear is nitrided and ground,

$= 0{,}67$ (95 British) if gear is carburised, hardened and ground.

For an idler gear, C should be increased by 60 per cent.

Where the teeth of gears made of through-hardened steels are finished by an approved post-hobbing process, or profile ground, or where it can be demonstrated in advance that the finish and profile of the teeth are equivalent, U may be increased by up to 25 per cent for a specified minimum ultimate tensile strength not exceeding 88 kg/mm^2 (56 ton/in^2). For higher specified tensile strengths, U may be taken as 0,49 (70 British).

TABLE H 3.1

HEAT TREATMENT AND SURFACE CONDITIONS		S			
PINION	WHEEL	TURBINE GEARING		OIL ENGINE GEARING	
		Metric value	*British value*	*Metric value*	*British value*
Through-Hardened	Through-Hardened	Lower value of $S_1 + 63$ or $\left(\frac{9+G}{10}\right)S_2+63$	Lower value of $S_1 + 40$ or $\left(\frac{9+G}{10}\right)S_2+40$	Lower value of $S_1 - 8$ or $\left(\frac{9+G}{10}\right)S_2 - 8$	Lower value of S_1-5 or $\left(\frac{9+G}{10}\right)S_2 - 5$
Carburised, Hardened and Ground / Nitrided after post-hobbing by an approved process or Nitrided and Ground	Through-Hardened	345 (provided $S_2 \geqslant 63$)	220 (provided $S_2 \geqslant 40$)	$\left(\frac{9+G}{10}\right)S_2 - 8$	$\left(\frac{9+G}{10}\right)S_2-5$
Carburised, Hardened and Ground / Nitrided after post-hobbing by an approved process or Nitrided and Ground	Induction-Hardened and Ground	470	300	300	190
Nitrided after post-hobbing by an approved process or Nitrided and Ground	Nitrided after post-hobbing by an approved process or Nitrided and Ground	535	340	345	220
Carburised, Hardened and Ground	Carburised, Hardened and Ground	570	360	380	240

The core tensile strength for surface-hardened steels must not be less than 79 kg/mm² (50 ton/in²).

Alternative proposals to the foregoing together with calculations may be submitted for special consideration.

CONSTRUCTION

Gear Wheels and Pinions

308 Where wheels are of cast construction any radial slots in the periphery are to be fitted with permanent chocks before shrinking-on the rim.

When bolts are used to secure side plates to rim and hub, the bolts are to be a tight fit in the holes and the nuts are to be suitably locked by means other than welding.

When welding is employed in the construction of wheels, the welding procedure is to be approved in the first instance by the Surveyors before work is commenced. For this purpose, test specimens representative of the welded joints used in the construction of the wheel are to be provided for examination and mechanical test. Sections are also to be taken from the test joints at positions selected by the Surveyors, and are to be macro-etched to verify that the welds are sound. Wheels are to be stress relieved after welding. All welds are to have a smooth surface and even contour and are to be proved by magnetic crack detection methods.

In general, arrangements are to be made so that the interior structure of the wheel may be examined. Alternative proposals will be specially considered.

Accuracy of Gear Cutting and Alignment

309 Turbine gearing is to be cut only on machines which are maintained at a high standard of accuracy. When large gears are designed with loading factors exceeding $K = 0{,}56$ (80 British), any hobbing machines used in their production are to operate under conditions of temperature control.

The accuracy of gear-cutting and alignment of pinions and wheels is to be demonstrated in the workshop to the satisfaction of the Surveyors.

Balance of Gear Pinions and Wheels

310 For turbine gearing, all pinions, gear wheels and flexible coupling sleeves whose maximum designed speed of rotation exceeds 1000 revolutions per minute are to be dynamically balanced. Where the speed of rotation is 1000 revolutions per minute or less, these components are to be statically or, alternatively, dynamically balanced.

Parts of couplings, etc., which are to be fixed to the gear in service shall normally be attached before balancing.

For oil engine gearing, all pinions, gear wheels and flexible couplings are to be statically or dynamically balanced as for turbine gearing. Balancing may, however, be omitted provided these rotating components are of solid forged construction or have a solid forged centre with shrunk-on rim, and in both cases are machined to give a concentric and uniform cross-section.

Gear Cases

311 Gear cases are to be of rigid design and if welding is employed in their construction they are to be stress relieved on completion (*see* H 107).

Inspection openings are to be provided at the peripheries of gear cases to enable the teeth of pinions and wheels to be readily examined. Where the construction of gear cases is such that sections of the structure cannot readily be moved for inspection purposes, access openings of adequate size are also to be provided at the ends of the gear cases to permit examination of the structure of the wheels. Their attachment to the shafts is to be capable of being examined by removal of bearing caps or by equivalent means.

Trials

312 Prior to full power sea trials, the teeth of pinions and wheels are to be thinly coated with copper sulphate, an approved spirit lacquer, or other equivalent. After these trials, the marking revealed by inspection is to indicate freedom from hard bearing and not less than 70 per cent contact across the effective face width with satisfactory contact over the involute profile. Where the teeth of gears made of through-hardened steels are finished by an approved post-hobbing process, or profile ground, or where it can be demonstrated in advance that the finish and profile of the teeth are equivalent, and the increase in loading permitted by 306 and 307 is required, not less than 90 per cent contact across the effective face width should be indicated.

The sea trials are to be of sufficient duration to prove the gears. On conclusion, all gears are to be opened up sufficiently to permit the Surveyors to make an inspection of the teeth.

Cross-reference

313 For lubricating oil systems, *see* E 9.

Section 4

PROPELLERS

Materials

401 Where bronze or cast steel is used for propellers or propeller blades, the materials should comply with the relevant requirements of Chapter Q, or an approved specification.

Cast iron propellers are to be made of a high duty iron of at least 27 kg/mm² (17 ton/in²) tensile strength, or of a nodular or spheroidal graphite ductile type cast iron.

402 A plan, in triplicate, of the propeller is to be submitted for approval, together with the following particulars:—

	Nomenclature and Units to be used in formulæ
Maximum blade thickness of the expanded cylindrical section considered	T in mm (in)
Maximum shaft or brake horse power (*see* H 105)	H
Revolutions per minute of the propeller at maximum power	R
Propeller diameter	D in metres (feet)
Pitch at 25 per cent radius (for solid propellers only)	$P_{0.25}$ in metres (feet)
Pitch at 35 per cent radius (for controllable pitch propellers only)	$P_{0.35}$ in metres (feet)
Pitch at 60 per cent radius	$P_{0.6}$ in metres (feet)
Pitch at 70 per cent radius	$P_{0.7}$ in metres (feet)
Length of blade section of the expanded cylindrical section at 25 per cent radius (for solid propellers only)	$L_{0.25}$ in mm (in)
Length of blade section of the expanded cylindrical section at 35 per cent radius (for controllable pitch propellers only)	$L_{0.35}$ in mm (in)
Length of blade section of the expanded cylindrical section at 60 per cent radius	$L_{0.6}$ in mm (in)
Rake at blade tip measured at shaft axis (backward rake positive, forward rake negative)	A in mm (in)
Number of blades	N
Developed area ratio	B
Material: Chemical composition, also mechanical properties and density (if not included in Table H 4.1)	

TABLE H 4.1

Material	Metric			British		
	Specified Minimum Tensile Strength kg/mm²	G Density g/cm³	U Allowable Stress kg/mm²	Specified Minimum Tensile Strength ton/in²	G Density lb/in³	U Allowable Stress lb/in²
Cast Iron (Grey or Low Alloy)	27	7,2	1,75	17	0·26	2500
Spheroidal Graphite or Nodular Cast Iron	44	7,3	2,1	28	0·26	3000
Carbon and Low Alloy Steels	44	7,9	2,1	28	0·29	3000
13% Chromium Stainless Steels	55	7,7	4,2	35	0·28	6000
Chromium-Nickel Austenitic Stainless Steels	55	7,9	4,2	35	0·29	6000
5% Nickel 8% Aluminium Bronzes	65	7,7	5,7	41·3	0·28	8100
8% Aluminium 12% Manganese Bronzes	65	7,5	5,7	41·3	0·27	8100
Manganese Bronzes	45	8,3	4,0	28·6	0·30	5700

Minimum Blade Thickness

403 The thickness of the propeller blades at the root (25 per cent radius for solid propellers, 35 per cent radius for controllable pitch propellers) neglecting any increase due to fillets, and at 60 per cent radius is not to be less than:—

$$\mathsf{T} = \frac{\mathsf{KCA}}{\mathsf{EFULN}} + 10\sqrt{\frac{24\,000\mathsf{MH}}{\mathsf{EFRULN}}}\ \text{mm}$$

$$\left(\mathsf{T} = \frac{\mathsf{KCA}}{\mathsf{EFULN}} + 2{\cdot}95\sqrt{\frac{24\,000\mathsf{MH}}{\mathsf{EFRULN}}}\ \text{in}\right)$$

where $\mathsf{L} = \mathsf{L}_{0,25}$, $\mathsf{L}_{0,35}$ or $\mathsf{L}_{0,6}$ as appropriate,

$$\mathsf{K} = \frac{\mathsf{GBD^3R^2}}{6600}$$

$$\left(\mathsf{K} = \frac{\mathsf{GBD^3R^2}}{150}\ \text{British}\right)$$

G and U = material constants (*see* Table H 4.1).

For cases where the composition of the propeller material is not specified in Table H 4.1, or where propellers of the cast irons and carbon and low alloy steels shown in this Table are provided with an approved method of cathodic protection, special consideration will be given to the value of U.

E = 1 for aerofoil sections with trailing edge washback,

E = 1,25 for aerofoil sections without trailing edge washback.

For other blade section shapes, the value of E may be adjusted in the ratio

$$\frac{\text{actual face modulus}}{0{,}09\ \mathsf{T^2L}}$$

For solid propellers at 25 per cent radius:—

$$\mathsf{C} = 1$$

$$\mathsf{F} = \frac{\mathsf{P}_{0,25}}{\mathsf{D}} + 0{,}8$$

$$\mathsf{M} = 1 + \frac{3{,}75\mathsf{D}}{\mathsf{P}_{0,7}} + 2{,}8\frac{\mathsf{P}_{0,25}}{\mathsf{D}}$$

For controllable pitch propellers at 35 per cent radius:—

$$\mathsf{C} = 1{,}4$$

$$\mathsf{F} = \frac{\mathsf{P}_{0,35}}{\mathsf{D}} + 1{,}6$$

$$\mathsf{M} = 1{,}35 + \frac{5\mathsf{D}}{\mathsf{P}_{0,7}} + 2{,}6\frac{\mathsf{P}_{0,35}}{\mathsf{D}}$$

For all propellers at 60 per cent radius:—

$$C = 1{,}6$$

$$F = \frac{P_{0,6}}{D} + 4{,}5$$

$$M = 1{,}35 + \frac{5D}{P_{0,7}} + 1{,}35\,\frac{P_{0,6}}{D}$$

For propellers of unusual design, or where the propeller is intended for more than one operating regime, such as towing or trawling, a detailed stress computation for the blades is to be submitted for consideration.

Section 5

STRENGTHENING FOR NAVIGATION IN ICE

General

501 Where the notation "Ice Class 1*, 1, 2 or 3" is desired, the following requirements are to be complied with, so far as these are applicable.

Power of Propelling Machinery

502 The power delivered to the propeller shafting (shp) is not to be less than C L B

where L = length of ship, between perpendiculars, in metres (feet),

B = breadth of ship, moulded, in metres (feet),

C = 2,1 (0·195 British) for Class 1*
1,79 (0·166 British) for Class 1
1,31 (0·122 British) for Class 2
0,98 (0·091 British) for Class 3.

Turbines

503 Where turbines are used for the propulsion of ships intended for Class 1*, 1 or 2 ice strengthening, the propeller shafting is to be driven by electrical or other approved means capable of protecting the turbines from shock.

Electric Motors

504 Where direct current electric motors are used for the propulsion of ships intended for Class 1*, 1 or 2 ice strengthening, provision is to be made for automatically limiting the transmitted torque to a safe value.

Materials

505 The propulsion shafting is to be of steel and the associated couplings are to be of steel or other approved material. For the material of screwshafts, *see* Q 601 to Q 610.

506 Propellers and propeller blades are to be of cast carbon steel, alloy steel or bronze having tensile strength of not less than 44 kg/mm^2 (28 ton/in^2). The material is to comply with the requirements of Q 5 or Q 9.

Main Engine Shafting, Gearing and Propellers

507 The diameters of the shafting as required by the rules for ocean-going service are to be increased by the percentages stated in Table H 5.1. No increase in the diameter of crank shafts of oil engines is required.

If gearing is fitted between the engine and propeller shafting, the gearing is to be designed and constructed to transmit torque in excess of that corresponding to the engine power by the percentages given in Table H 5.1.

The thicknesses of the blades at the root and at 60 per cent radius as required by H 403 are to be increased by the percentages stated in Table H 5.1.

TABLE H 5.1

Class	1*	1	2	3
Gearing, torque increase ...	50%	25%	15%	—
Thrust and intermediate shaft, increase in diameter	12%	8%	4%	—
Screw shaft, increase in diameter	20%	15%	8%	5%
Propeller, increase in blade thickness...	35%	25%	15%	8%

Minimum Propeller Blade Tip Thickness

508 The tip thickness t of the blade at 95 per cent radius is not to be less than that obtained by the following formula for Class 1*, 1, 2 and 3 ice strengthening:—

$$t = 0{,}14\,(T + 57)\,\sqrt[3]{\frac{44}{S}}\ \text{mm}$$

$$\left(t = 0{\cdot}14\,(T + 2{\cdot}25)\,\sqrt[3]{\frac{28}{S}}\ \text{in}\right)$$

where T = blade root thickness required for appropriate Class, in mm (in),

S = Specified minimum tensile strength of material, in kg/mm^2 (ton/in^2).

The edges of the blades are to be suitably thickened for the operating conditions but are not to be less than 50 per cent of the required tip thickness t, measured at 1,25 times tip thickness t from the edge. For controllable pitch propellers, this requirement need only be applied to the leading edges of the blades.

Ship Side Valves

509 The sea inlet and overboard discharge valves which are situated at or below the maximum load line, are to be provided with a low pressure steam or compressed air connection for clearing purposes (*see* E 267 and E 271).

Where steam is not available for clearing, it is recommended that arrangements be made for supplying water for machinery cooling purposes by circulating from ballast tank(s) of adequate capacity preferably situated in the double bottom. Such tank(s) are to be used only for storage of water ballast or fresh water.

510 Connections are to be fitted between the cooling water overboard discharge lines and sea inlets for main and auxiliary engine cooling water systems so that warm water may be used to assist in maintaining the suction pipes free from ice.

Where the cooling water inlet valves are fitted to a common water box, the connections from the cooling water discharge lines may be led to the water box in a position as near as possible to the inlet valves.

511 In motor ships where clearing steam is not available, fire pumps are to be provided with suctions from the main cooling water inlet pipe.

Cross-references

512 For hull requirements, *see* D 24, and for general requirements for ship side valves, *see* E 267 to E 271.

Section 6

GENERAL REQUIREMENTS FOR OIL ENGINES AND STARTING AIR COMPRESSORS

Ventilation

601 Special attention is to be given to the ventilation of the engine room.

Relief Valves

602 Cylinder relief valves are to be fitted to engines having cylinders over 230 mm (9·0 in) bore. The valves are to be loaded to not more than 40 per cent above the designed maximum pressure and are to discharge where no damage can occur.

In the case of auxiliary engines, consideration will be given to the replacement of the relief valve by an efficient warning device of overpressure in the cylinder.

603 Scavenge manifolds of two-stroke main engines are to be provided with explosion relief valves.

Exhaust Systems

604 The exhaust pipes and silencer are to be water cooled or efficiently lagged to prevent damage by heat; if the exhaust is led overboard near the water-line, means are to be provided to prevent water from being syphoned back to the engine.

Where the exhaust is cooled by water spray, the exhaust pipes are to be self-draining overboard.

Where the exhausts of two or more engines are led to a common silencer or exhaust gas-heated boiler or economiser an isolating device is to be provided in each exhaust pipe.

For alternatively fired furnaces of boilers using exhaust gases and oil fuel, the exhaust gas inlet pipe is to be provided with an isolating device and interlocking arrangements whereby oil fuel can only be supplied to the burners when the isolating device is closed to the boiler.

In two-stroke main engines fitted with exhaust gas turbo-blowers which operate on the impulse systems, provision is to be made to prevent broken piston rings entering the turbine casing and causing damage to blades and nozzle rings.

Governors and Overspeed Protective Devices

605 An efficient governor is to be fitted to each main engine so adjusted that the speed does not exceed that for which the engine is to be classed by more than 15 per cent.

606 Auxiliary engines intended for driving electric generators are to be fitted with governors which, with fixed setting, are to control the speed within the following limits:—

> 10 per cent momentary variation and 5 per cent permanent variation in speed when full load is suddenly taken off or, when after having run on no-load for at least 15 minutes, not less than 70 per cent full load is suddenly applied, followed by the remaining 30 per cent, except in the case of emergency generators which are to be capable of accepting full load under the same test conditions. For A.C. installations, the permanent speed variations of the machines intended for parallel operation are to be equal within a tolerance of $\pm 0,5$ per cent.

607 Each main engine developing 300 BHP or over which can be declutched or which drives a controllable (reversible) pitch propeller, also each auxiliary engine developing 300 BHP and over for driving an electric generator, is to be fitted with an approved overspeed protective device.

The overspeed protective device, including its driving mechanism, is to be independent of the governor required by 605 or 606 and is to be so adjusted that the speed does not exceed that for which the engine and its driven machinery are to be classed by more than 20 per cent for main engines and 15 per cent for auxiliary engines.

Starting Arrangements

608 Equipment for starting the main and auxiliary engines is to be provided so that the necessary initial charge of starting air or initial electric power can be developed on board ship without external aid. If for this purpose an emergency air compressor or electric generator is required, these units are to be power driven by hand starting oil engine or steam engine, except in the case of small installations where a hand operated compressor of approved capacity may be accepted. Alternatively, other devices of approved type may be accepted as a means of providing the initial start.

609 Two or more starting and manœuvring air compressors are to be fitted of sufficient total capacity for the requirements of the main engines.

The compressors are to be so designed that the temperature of the air discharged to the starting air receivers will not substantially exceed 93°C (200°F) in service. A small fusible plug or an alarm device operating at 121°C (250°F) is to be provided on each compressor to give warning of excessive air temperature. The emergency air compressor is excepted from these requirements.

Each compressor is to be fitted with a safety valve so proportioned and adjusted that the accumulation with the outlet valve closed will not exceed 10 per cent of the maximum working pressure. The casings of the cooling water spaces are to be fitted with a safety valve or bursting disc so that ample relief will be provided in the event of the bursting of an air cooler tube. It is recommended that compressors be cooled by fresh water.

610 Where the main engines are arranged for air starting the total air receiver capacity is to be sufficient to provide, without replenishment, not less than twelve consecutive starts of each main engine if of the reversible type and not less than six consecutive starts if of the non-reversible type. In passenger ships, at least two air receivers are to be provided. For scantlings and fittings of air receivers, *see* J 2, J 3 and J 6.

611 Where main engines are fitted with electric starters, two batteries are to be fitted. Each battery is to be capable of starting the engines when cold and the combined capacity is to be sufficient without recharging to provide the number of starts of the main engines as required by 610. In other respects batteries are to comply with the requirements of M 13.

Starting Air Pipe Systems and Safety Fittings

612 In designing the compressed air installation care is to be taken that the compressor air inlets will be located in an atmosphere reasonably free from oil vapour or alternatively an air duct from outside the machinery space is to be led to the compressors.

The air discharge pipe from the compressors is to be led direct to the starting air receivers. Provision is to be made for intercepting and draining oil and water in the air discharge for which purpose a separator or filter is to be fitted in the discharge pipe between compressors and receivers.

The starting air pipe system from receivers to main and auxiliary engines is to be entirely separate from the compressor discharge pipe system. Stop valves on the receivers are to permit of slow opening to avoid sudden pressure rises in the piping system. Valve chests and fittings in the piping system are to be of ductile material.

Drain valves for removing accumulations of oil and water are to be fitted on compressors, separators, filters and receivers. In the case of any low-level pipe lines, drain valves are to be fitted to suitably located drain pots or separators.

The starting air piping system is to be protected against the effects of explosions by the following arrangements. An isolating non-return valve or equivalent is to be provided at the starting air supply connection to each engine. In direct reversing engines bursting discs or flame arresters are to be fitted at the starting valves on each cylinder; in non-reversing and auxiliary engines at least one such device is to be fitted at the supply inlet to the starting air manifold on each engine. The fitting of bursting discs or flame arresters may be waived in small ships where the power of the main engine is less than 1500 bhp provided all the pipes in the system are made at least twice as thick as required by E 506 or E 512 and E 513.

Alternative safety arrangements may be submitted for consideration.

Crank Case Safety Fittings

613 Crank cases are to be provided with lightweight spring-loaded valves or other quick-acting and self-closing devices to relieve the crank cases of pressure in the event of

an internal explosion and to prevent any inrush of air thereafter. The valves are to be designed to open at a low pressure of about 0,1 kg/cm^2 (1 lb/in^2).

The valve lids are to be made of ductile material capable of withstanding the shock of contact with stoppers at the full open position.

The discharge from the valves is to be shielded where necessary by flame guard or flame trap to minimise the possibility of danger and damage arising from the emission of flame.

614 In engines having cylinders not exceeding 200 mm (8 in) bore and having a crank case gross volume not exceeding 0,6 m^3 (20 ft^3), relief valves may be omitted.

In engines having cylinders exceeding 200 mm (8 in) but not exceeding 250 mm (10 in) bore, at least two relief valves are to be fitted; each valve is to be located at or near the ends of the crank case. Where the engine has more than 8 crank throws an additional valve is to be fitted near the centre of the engine.

In engines having cylinders exceeding 250 mm (10 in) but not exceeding 300 mm (12 in) bore at least one relief valve is to be fitted in way of each alternate crank throw with a minimum of two valves. For engines having 3, 5, 7, 9 etc. crank throws, the number of relief valves is not to be less than 2, 3, 4, 5 etc. respectively.

In engines having cylinders exceeding 300 mm (12 in) bore at least one valve is to be fitted in way of each main crank throw.

615 The combined free area of the crank case relief valves fitted on an engine is not to be less than 115 cm^2/m^3 (0·5 in^2/ft^3) based on the volume of the crank case.

The free area of each relief valve is not to be less than 45 cm^2 (7 in^2).

NOTE (1) The free area of the relief valve is the minimum flow area at any section through the valve when the valve is fully open.

(2) In determining the volume of the crank case for the purpose of calculating the combined free area of the crank case relief valves, the volume of the stationary parts within the crankcase may be deducted from the total internal volume of the crank case.

616 Alarms giving warning of the overheating of engine running parts, indicators of excessive wear of thrusts and other parts, and detectors of smoke in the crank case are recommended as means for reducing the explosion hazard. These devices should be arranged to give an indication of failure of the equipment or of the instrument being switched off when the engine is running.

617 Crank cases and their doors are to be of robust construction and the doors are to be securely fastened so that they will not be readily displaced by an explosion.

618 Where crank case vent pipes are fitted, they are to be made as small as practicable to minimise the inrush of air after an explosion. Vents from crank cases of main engines are to be led to a safe position on deck or other approved position.

Lubricating oil drain pipes from engine sump to drain tank are to be submerged at their outlet ends. Where two or more engines are installed, vent pipes, if fitted, and lubrication oil drain pipes are to be independent to avoid intercommunication between crank cases.

619 Crank cases of starting air compressors are to be fitted with explosion relief devices as required for auxiliary engines in cases where the crank case volume is 0,60 m^3 (20 ft^3) and over.

Crank Case Lighting

620 Where interior lighting is provided it is to be flame proof in relation to the interior and details are to be submitted for approval. No wiring is to be fitted inside the crank case.

Hydraulic Tests

621 In general, items are to be tested by hydraulic pressure as indicated in Table H 6.1. Where design features are such that modifications to the test requirements shown in Table H 6.1 are necessary, alternative proposals for hydraulic tests are to be submitted for special consideration.

Astern Power

622 Ships are to have sufficient power for going astern to secure proper control of the ship in all normal circumstances.

Trials

623 The sea trials are to be of sufficient duration to prove the machinery under power and normal manœuvring conditions.

It is to be demonstrated that the capacity of starting air receivers is adequate to provide the required number of starts of the main engines.

In the case of passenger ships, the ability of the machinery to reverse the direction of thrust of the propeller in sufficient time, under normal manœuvring conditions, and so bring the ship to rest from maximum ahead service speed is to be demonstrated at the sea trials.

All trials are to be to the Surveyor's satisfaction.

Cross-references

624 The pumping arrangements, including cooling water and lubricating oil systems, are to comply with the requirements of Chapter E.

625 Oil fuel pipe systems, tanks and their fittings are to comply with the requirements of D 19 and Chapter E.

626 For lists of spare gear to be carried, *see* Chapter K.

TABLE H 6.1

ITEM		TEST PRESSURE
Fuel injection system	Pump body, pressure side Valve Pipe	The lesser of 1,5P or P+300 kg/cm² (P+4250 lb/in²)
Cylinder cover, cooling space Cylinder liner, internally and over the whole length of cooling space Piston crown, cooling space (after assembly with piston rod)		7 kg/cm² (100 lb/in²)
Cylinder jacket, cooling space Exhaust valve, cooling space Turbo-blower, cooling space Exhaust pipe, cooling space Coolers, each side Engine driven pumps (oil, water, fuel, bilge)		The greater of 4 kg/cm² (55 lb/in²) or 1,5P
Air compressor, including cylinders, covers, intercoolers and aftercoolers	air side	1,5P
	water side	The greater of 4 kg/cm² (55 lb/in²) or 1,5P
Scavenge pump cylinder		4 kg/cm² (55 lb/in²)

P is the maximum working pressure in the item concerned.

Section 7

WELDED STRUCTURES FOR OIL ENGINES

General

701 The requirements of this section are applicable to engines for main propelling purposes.

Plans

702 Before construction is commenced plans of bedplates, crank cases, frames and entablatures, including details of the welded joints, materials, electrodes and heat treatment are to be submitted for consideration.

An outline of the welding procedure and fabrication method and sequence is also to be submitted for information.

NOTE: It will not be necessary for plans and particulars to be submitted for each ship provided the basis plans for the engine size and type have previously been approved as meeting the requirements of these Rules. Any alterations to basis design, materials and manufacturing procedure are to be re-submitted for consideration.

Materials

703 Plates, sections, forgings and castings are to be of welding quality to an approved specification with a carbon content generally not exceeding 0,23 per cent, and are to be tested in accordance with the requirements of Chapter Q. Steels with higher carbon contents may be approved subject to special tests to prove weldability.

Construction

704 Plates and weld preparations are to be accurately machined or flame-cut to shape. Flame-cut surfaces are to be cleaned by machining or grinding; if the flame-cut surfaces are smooth, wire brushing may be accepted.

Before welding is commenced the component parts of bedplates and framework are to be accurately fitted and aligned. The welding is to be done in positions free from draughts and is to be downhand wherever practicable. Electrodes are to be of an approved type. Pre-heating is to be adopted when welding heavy plates or sections. The finished welds are to have an even surface and be free from undercutting. Welds attaching bearing housings to the transverse girders are to have a smooth contour and if necessary are to be made smooth by grinding.

Welded Joints

705 Joints in parts of the engine structure which are stressed by the main gas or inertia loads are to be designed as continuous full strength welds and for complete fusion of the joint. They are to be so arranged that, in general, welds do not intersect, and that welding and inspection can be effected without difficulty. Abrupt changes in plate section are to be avoided and where plates of substantially unequal thickness are to be butt welded, the thickness of the heavier plate is to be gradually tapered to that of the thinner plate. Tee joints are to be made with full bevel or equivalent weld preparation to ensure full penetration.

In single plate transverse girders the castings for main bearing housings are to be formed with web extensions which can be butt welded to the flange and vertical web plates of the girder. Stiffeners in the transverse girder are to be attached to the flanges by full penetration welds.

Heat Treatment

706 Bedplates are to be stress relieved except for engine types where the bedplate as a whole is not subjected to direct loading from the cylinder pressure. For the latter types only the transverse girder assemblies need be stress relieved.

Stress relieving is to be done by heating the welded structure uniformly and slowly to a temperature between 580°C to 650°C (1080°F to 1200°F), holding that tempera-

ture for not less than one hour per 25 mm (1 in) of maximum plate thickness and thereafter allowing the structure to cool slowly in the furnace.

Inspection

707 Welded engine structures are to be examined during fabrication, special attention being given to the fit of component parts of major joints prior to welding. On completion of welding and stress relieving, all welds are to be examined. Welds in transverse girder assemblies are to be crack detected by an approved method to the satisfaction of the Surveyors. Other joints are to be similarly tested if required by the Surveyors.

The whole of the welding work is to be to the satisfaction of the Surveyors.

DESIGN RECOMMENDATIONS

It is recommended that bedplates and major components of engine structures should be made with a minimum number of welded joints.

Double welded butt type joints should be adopted wherever possible in view of their superior fatigue strength.

Girder and frame assemblies should, as far as possible, be made from one plate or slab, shaped as necessary, rather than by welding together a number of small pieces.

Steel castings should be used for parts which would otherwise require complicated weldments.

Care should be taken to avoid stress concentrations such as sharp corners and abrupt changes in section.

Section 8

GENERAL REQUIREMENTS FOR STEAM AND GAS TURBINES

Scope

801 The following requirements are applicable to steam and gas turbines for main propulsion and for essential auxiliary services where powers exceed 150 shp. Features of gas turbine machinery which are not included in this section will be specially considered.

Plans

802 The following plans are to be submitted for consideration, together with particulars of materials and of maximum shaft horse powers and revolutions per minute (*see* H 105). The pressures and temperatures applicable at maximum shaft horse power and under the emergency conditions of 838 are to be stated or indicated on the plans.

1. General arrangement.
2. Sectional assembly.
3. Rotors and couplings.
4. Cylinders.
5. Combustion chamber and heat exchangers.

For main steam turbines plans 1, 2 and 3 are required in all cases and 4 when the cylinders are of welded construction. In general for auxiliary steam turbines no plans need be submitted. For main and auxiliary gas turbines plans 1 to 5 are required.

Where rotors and cylinders are of welded construction plans showing details of the welded joints are also to be submitted for consideration.

Materials

803 Plates, forgings, castings and pipes used in the construction of turbine cylinders, rotors, discs, couplings and other important components are to be of approved composition and be tested in accordance with the relevant requirements of Chapter Q, or of an approved Specification.

804 In the selection of materials for high temperature applications in advanced steam and gas turbines consideration is to be given to their creep strength, corrosion resistance and scaling properties at working temperatures to ensure satisfactory performance and long life under service conditions.

805 Turbine rotors and discs are to be of forged steel. For carbon and carbon-manganese steel forgings the specified range of tensile strength is not to exceed 10 kg/mm^2 (6·3 ton/in^2) within the general limits of 45 and 70 kg/mm^2 (28·6 and 44·5 ton/in^2). For alloy steel rotor forgings the specified range is not to exceed 15 kg/mm^2 (9·5 ton/in^2) within the general limits of 45 and 95 kg/mm^2 (28·6 and 60·3 ton/in^2). For discs and other alloy steel forgings the specified range is not to exceed 15 kg/mm^2 (9·5 ton/in^2) within the general limits of 45 and 115 kg/mm^2 (28·6 and 73 ton/in^2).

When it is proposed to use a steel of higher tensile strength full details are to be submitted for approval. (*See* Q 631 to Q 640).

806 Turbine cylinder castings are to be of approved material suitable for the working metal temperature. Ordinary cast iron is not to be used for temperatures exceeding 260°C (500°F). The castings are to be stress relief heat treated after rough machining, except that this requirement may be waived for small castings at the Surveyors' discretion. The stress relieving temperature is not to exceed the tempering temperature. (*See* Q 504 and Q 507 for Steel Castings.)

Stability Testing of Turbine Rotors

807 All solid forged H.P. steam and gas turbine rotors intended for main propulsion service where the inlet steam or gas temperature exceeds 400°C (750°F) are to be subjected to at least one thermal stability test. This requirement is also applicable to rotors fabricated as in 821. The test may be carried out at the Forge or Turbine Builders' Works (*a*) after heat treatment and rough machining of the forging, or (*b*) after final machining, or (*c*) after final machining and blading of the rotor. The stabilising test temperature is not to be less than 28 degC (50 degF) above the maximum steam or gas temperature to which the rotor will be exposed and not more than the tempering temperature of the rotor material. For details of a recommended test procedure and limits of acceptance, *see* Q 637(e). Other test procedures may be adopted if approved.

Where main turbine rotors are subjected to thermal stability tests at both Forge and Turbine Builders' Works the foregoing requirements are applicable to both tests. It is not required that auxiliary turbine rotors be tested for thermal stability, but if such tests are carried out, the requirements for main turbine rotors will be generally applicable.

Design and Construction

808 In the design and arrangement of turbine machinery adequate provision is to be made for the relative thermal expansion of the various turbine parts, and special attention is to be given to minimising casing and rotor distortion under all operating conditions.

809 Indicators for determining the axial position of rotors relative to their casings and for showing the longitudinal expansion of casings at the sliding feet, if fitted, are to be provided for main turbines. The latter indicators should be fitted at both sides and be readily visible.

810 Pipes and ducts connected to turbine casings are to be so designed that no excessive thrust loads or moments are applied by them to the turbines. Gratings and any fittings in way of sliding feet or flexible-plate supports are to be so arranged that casing expansion is not restricted. Where main turbine seatings incorporating a tank structure are proposed, consideration is to be given to the temperature variation of the tank in service to ensure that turbine alignment will not be adversely affected.

811 In arranging the gland-sealing system of steam turbines the pipes are to be made self-draining and every precaution is to be taken against the possibility of condensed steam entering the glands and turbines. The steam supply to the gland-sealing system is to be fitted with an effective drain trap. In the air ejector re-circulating water system the connection to the condenser is to be so located that water cannot impinge on the L.P. rotor or casing.

812 Turbine bearings are to be so disposed and supported that lubrication is not adversely affected by heat flow from adjacent hot parts of the turbine. Effective means are to be provided for intercepting oil leakage and preventing oil from reaching high temperature glands and casings. Drainage openings from oil baffles are to be amply large.

813 Discs of built rotors fitted by shrinking are to be secured with keys, dowels or other approved means in main turbines.

814 Smooth fillets are to be provided at abrupt changes of section of rotors, spindles, discs, blade roots and tenons. The rivet holes in blade shrouds are to be rounded and radiused on top and bottom surfaces and tenons to be radiused at junction with blade tips. Balancing holes in discs are to be well rounded and polished.

815 Surveyors are to be satisfied as to the workmanship and riveting of blades to shroud bands and that the blade tenons are free from cracks, particularly with high tensile blade material. Test samples are to be sectioned and examined and pull-off tests made if considered necessary by the Surveyors.

816 All rotors, as finished-bladed and complete with half coupling, are to be dynamically balanced in a machine of appropriate sensitivity for the size of rotor, to the Surveyors' satisfaction.

817 The turning gear for all propulsion turbines is to be power-driven and, if electric, is to be continuously rated.

Welded Components

818 Turbine rotors, cylinders and associated components fabricated by means of welding will be considered for acceptance if constructed by firms whose works are properly equipped to undertake welding of equivalent standards, for rotor and cylinders respectively, to those required by the Rules for Class 1 and Class 2/1 Welded Pressure Vessels. (*See* J 4).

819 Welded combustion chambers, heat exchangers, gas collector vessels, pressure ducting and piping are to comply with the relevant sections of Chapters J (pressure vessels) and E (pipes).

820 Materials used in the construction of turbine rotors, cylinders, diaphragms, condensers, etc., are to be of welding quality.

821 Where it is proposed to construct rotors from two or more forged components joined by welding, full details of the chemical composition, mechanical properties and heat treatment of the materials, together with electrode particulars, an outline of the welding procedure, method of fabrication and heat treatment are to be submitted for consideration.

822 Joints in rotors and major joints in cylinders are to be designed as full-strength welds and for complete fusion of the joint.

823 In the first instance and before work is commenced the Surveyors are to be satisfied that the desired quality of welding is attainable with the proposed welding procedure, and for this purpose test specimens representative of the welded joints are to be provided for radiographic examination and mechanical tests. For cylinders the mechanical tests of butt joints are to include tensile, bend and nicked bend tests as detailed in J 4. For diaphragms, nozzle plates etc., representative samples are to be sectioned and macro-etched. For rotors the mechanical tests are to include tensile (all weld metal), tensile (joint), bend (transverse), bend (longitudinal) and macro tests as detailed in J 4 or such other tests as may be approved. In subsequent production, check mechanical tests are to be carried out at the Surveyors' discretion if the quality of the welding is found to be unsatisfactory.

824 Adequate preheating is to be employed for mild steel cylinders and components where the metal thickness exceeds 44 mm (1·75 in) and for all low alloy steel cylinders and components and for any part where necessitated by joint restraint.

825 Stress relief heat treatment is to be applied to all cylinders and associated components on completion of the welding of all joints and attached structures. (*See* J 440 for details of stress relief procedure, temperature and duration).

826 The heat treatment of welded rotors is to be carried out as approved.

827 Examinations by non-destructive methods are to be made of all cylinders and rotors on completion of heat treatment as follows:—

CYLINDERS.—Major stressed joints in pressure shells are to be radiographed if practicable; other joints such as nozzle plate and branch pipe connections and diaphragm joints are to be examined by crack detection methods.

ROTORS.—All joints are to be examined by radiography or other approved methods and by magnetic crack detection methods.

828 The whole of the welding work is to be to the satisfaction of the Surveyors.

Governors and other Safety Devices

829 An emergency overspeed governor is to be provided for main and auxiliary steam turbines so as to shut off the steam automatically and prevent the maximum designed speed being exceeded by more than 15 per cent.

830 Where two or more propulsion turbines are coupled to the same main gear wheel and only one emergency governor is provided, it is to be fitted to the L.P. ahead turbine. Hand trip gear for shutting off the steam in emergency is to be provided at the manœuvring platform.

831 Arrangements are to be made for the steam to the ahead propulsion turbines to be automatically shut off in the event of failure of the lubricating oil pressure. (*See* E 904 for emergency oil supply).

832 Where a turbine installation incorporates a reverse gear, electric transmission or reversible propeller, a speed governor in addition to, or in combination with, the emergency governor is to be fitted and is to be capable of controlling the speed of the unloaded turbine without bringing the emergency governor into action.

833 Auxiliary turbines intended for driving electric generators are to be fitted with speed governors which, with fixed setting, are to control the speed within the following limits:—

10 per cent momentary variation and 5 per cent permanent variation in speed when full load is suddenly taken off or put on, but for any A.C. installation the permanent speed variations of the machines intended for parallel operation are to be equal within a tolerance of $\pm$ 0,5 per cent.

834 Sentinel relief valves are to be provided at the exhaust ends or other approved positions of all main steam turbines and the valve discharge outlets are to be visible and suitably guarded if necessary. Where a low vacuum cut-out valve is provided the sentinel relief valve at the L.P. exhaust may be omitted.

835 Non-return valves or other means, which will prevent steam and water returning to the turbines, are to be fitted in bled steam connections.

836 Efficient steam strainers are to be provided close to the inlets to ahead and astern high pressure turbines, or alternatively at the inlets to the manœuvring valves.

837 The governing and other safety devices for propulsion gas turbine installations will be specially considered.

Emergency Arrangements

838 In single screw ships fitted with steam turbines having more than one cylinder, the arrangements are to be such that steam can be led direct to the L.P. turbine and either the H.P. or I.P. turbine can exhaust direct to the condenser. Adequate arrangements and controls are to be provided for these emergency conditions so that the pressure and temperature of the steam will not exceed those which the turbines and condenser can safely withstand.

Hydraulic Tests

839 Manœuvring valves are to be tested to twice the working pressure. The nozzle boxes of impulse turbines are to be tested to 1,5 times the working pressure.

The cylinders of all turbines are to be tested to 1,5 times the working pressure in the casing or to 2 kg/cm^2 (30 lb/in^2), whichever is the greater.

For test purposes the cylinders may be sub-divided with temporary diaphragms for distribution of test pressures.

Condensers are to be tested in the steam space to 1 kg/cm^2 (15 lb/in^2). The water space is to be tested to the maximum pressure which the pump can develop with the discharge valve closed plus 0,7 kg/cm^2 (10 lb/in^2), with a minimum test pressure of 2 kg/cm^2 (30 lb/in^2). Where the operating conditions are not known, the test pressure is to be not less than 3,5 kg/cm^2 (50 lb/in^2). *See* E 802.

Astern Power

840 Sufficient astern power is to be provided to maintain control of the ship in all normal circumstances.

The astern turbines of steam installations are to be capable of maintaining in free route astern 70 per cent of the ahead revolutions, corresponding to the maximum propulsion shaft horsepower for which the machinery is to be classed, for a period of at least 30 minutes without undue heating of the ahead turbines and condensers.

Similar conditions are to be complied with in gas turbine installations, including those with a continuously coupled ahead turbine and a separate prime mover for astern operation.

Where controllable pitch propellers are fitted the free route astern trial is to be carried out with the propeller blades set in the full astern position.

Trials

841 The sea trials are to be of sufficient duration to prove the machinery under power and normal manœuvring conditions. Where astern turbines or hydraulic reversing gear are fitted, astern running at 70 per cent of the full power ahead revolutions is to be demonstrated. The astern trial need only be of 15 minutes duration, but may be extended to 30 minutes at the Surveyors' discretion.

In the case of passenger ships, the ability of the machinery to reverse the direction of thrust of the propeller in sufficient time, under normal manœuvring conditions, and so bring the ship to rest from maximum ahead service speed is to be demonstrated at the sea trials.

All trials are to be to the Surveyors' satisfaction.

Cross-references

842 Turbines intended for driving electric generators are to comply with the requirements of M 401 and M 402.

843 The pumping arrangements, including cooling water and lubricating oil systems, are to comply with the requirements of Chapter E.

844 For lists of spare gear to be carried, *see* Chapter K.

23rd July, 1970

Chapter J

BOILERS AND OTHER PRESSURE VESSELS

General

The requirements of this Chapter are applicable to fired and unfired pressure vessels of seamless, fusion welded, and riveted construction, intended for marine services.

The pressure vessels are to be made in accordance with the requirements contained in the following sections, where applicable:—

Section 1. General Requirements,
,, 2. Design,
,, 3. Construction,
,, 4. Requirements for Fusion Welding,
,, 5. Manufacture and Workmanship,
,, 6. Mountings and Fittings,
,, 7. Pressure Vessels for the Carriage of Liquefied Petroleum Gases,
,, 8. Riveted Pressure Vessels.

Seamless pressure vessels are to be manufactured in accordance with the requirements of Chapter Q 6 or Q 7 where applicable, and tested by hydraulic pressure as for fusion welded pressure vessels (*see* J 445).

Section 1

GENERAL REQUIREMENTS

Design Pressure

101 The design pressure is the maximum permissible working pressure and is not to be less than the highest set pressure of any safety valve. The calculations made to determine the scantlings of the pressure parts are to be based on the design pressure adjusted, where necessary, to take account of pressure variations corresponding to the most severe operational conditions.

Note.—It is desirable that there should be a margin between the normal pressure at which the boiler or pressure vessel operates and the lowest pressure at which any safety valve is set to lift, to prevent unnecessary lifting of the safety valve.

Metal Temperature

102 The metal temperature "t", used to evaluate the allowable stress "f", is to be taken as the actual metal temperature expected under operating conditions for the pressure part concerned and is to be stated by the manufacturer when plans of the pressure parts are submitted for consideration. The following values are to be regarded as minimum subject to the overriding provision that "t" is not to be less than 250°C (482°F) and 100°C (212°F) in the case of fired and unfired pressure vessels respectively.

(1) For unfired pressure vessels and for the following parts of fired pressure vessels, viz., shells, drums or other pressure components not heated by hot gases and those parts adequately protected by insulation from hot gases, "t" is to be taken as the maximum temperature of the internal fluid.

(2) For pressure parts heated by hot gases, "t" is to be taken as not less than 25degC (45degF) in excess of the maximum temperature of the internal fluid.

In general, where any parts of boiler drums or headers are not protected by tubes and are exposed to radiation from the fire, or to the impact of hot gases, they are to be protected by a shield of good refractory materials or by other approved means.

Drums and headers of thickness greater than 30 mm (1·2 in) are not to be exposed to combustion gases having an anticipated temperature in excess of 650°C (1200°F) unless they are efficiently cooled by closely arranged tubes accommodated therein.

(3) For boiler, superheater, reheater and economiser tubes "t" is to be taken as indicated in J 222.

(4) For combustion chambers of the type used in horizontal wet-back boilers, "t" is to be taken as not less than 50degC (90degF) in excess of the maximum temperature of the internal fluid.

(5) For furnaces, fireboxes, rear tube plates of dry-back boilers and pressure parts subject to similar rates of heat-transfer, "t" is to be taken as not less than 90degC (162degF) in excess of the maximum temperature of the internal fluid.

Materials

103 Materials used in the construction of boilers and other pressure vessels are to be manufactured and tested in accordance with the requirements of Chapter Q.

Rolled steel plates are subject to the limitations of application indicated in Table J 1.1, and for approval purposes the grades of plates specified in Q 3 have been grouped as follows:—

Group 1 Carbon and carbon manganese steels 37 to 57 kg/mm² (23·5 to 36·2 ton/in²).

Group 2 Carbon and carbon manganese steels 52 to 62 kg/mm² (33 to 39·4 ton/in²).

Group 3 Low alloy steels.

As an alternative to the materials stated in Chapter Q consideration will be given to the use of:—

(*a*) Materials complying with national or proprietary specifications which give reasonable equivalence to the requirements of Chapter Q, *or*

(*b*) materials which have higher carbon content or alloy steels not specified in Chapter Q

provided in both cases details of the chemical composition, heat treatment and mechanical properties are submitted for approval.

Where materials, other than those specified in Chapter Q are proposed, the values of the properties to be used for deriving the allowable stress are to be subject to agreement by the Society.

Plans

104 Plans in triplicate of boilers, superheaters and economisers are to be submitted for consideration, as required by G 104. When plans of water tube boilers are submitted for approval particulars of the safety valves and their disposition on boiler and superheater, together with the estimated pressure drop through the superheater, are to be stated. The pressures proposed for the settings of boiler and superheater safety valves are to be indicated on the boiler plan.

In the case of fusion welded pressure vessels plans in triplicate, showing full constructional features of the vessel and dimensional details of the weld grooves for longitudinal and circumferential seams and attachments, together with particulars of the electrodes and of the mechanical properties of the materials are to be submitted before construction is commenced.

Allowable Stress

105 The term "allowable stress", designated by "f" in the following paragraphs, is the stress to be used in the formulæ for the calculation of scantlings of pressure parts.

The allowable stress "f" is the lowest of the following values; the material properties for the appropriate category, grade and tensile range of steel are indicated in Chapter Q.

Wrought Steel

Fired Pressure Vessels $f = \dfrac{E_t}{1,6}$ $f = \dfrac{R_{20}}{2,7}$ $f = \dfrac{S_R}{1,5}$

Unfired Pressure Vessels $f = \dfrac{E_t}{1,5}$ $f = \dfrac{R_{20}}{2,7}$ $f = \dfrac{S_R}{1,5}$

TABLE J 1.1

Application	Group of Steel	Tensile Strength limited to
Welded Pressure Vessels Class 1	1 2 3	
Welded Pressure Vessels Class 2/1	1 2	
Welded Pressure Vessels Class 2/2	1	37–52 kg/mm² (23·5–33 ton/in²)
Welded Pressure Vessels Class 3	1	37–52 kg/mm² (23·5–33 ton/in²)
Boiler furnaces, combustion chambers and flanged plates	1 2	42–62 kg/mm² (26·7–39·4 ton/in²)
Shells of all riveted boilers	1	42–57 kg/mm² (26·7–36·2 ton/in²)
Shells of riveted boilers with welded compensating rings and attachments.	1	42–52 kg/mm² (26·7–33 ton/in²)

where E_t = specified minimum lower yield stress or 0,2 per cent proof stress at temperature "t",

R_{20} = specified minimum tensile strength at room temperature,

S_R = average stress to produce rupture in 100 000 hours at temperature "t",

t = metal temperature (*see* 102).

The allowable stress for steel castings is to be taken as 80 per cent of the value determined by the method indicated above using the appropriate values for cast steel.

Where steel castings, which have been tested in accordance with Q 5 are also subjected to non-destructive tests, consideration will be given to increasing the allowable stress using a factor up to 90 per cent in lieu of the 80 per cent referred to above. Particulars of the non-destructive test proposals are to be submitted for consideration.

Joint Factors

106 Fusion welded pressure parts are to be made in accordance with J 4 and the following joint factors are to be used in the equations in J 2 where applicable.

Class of Welding	*Joint Factor*
Class 1	1,0
Class 2/1	0,85
Class 2/2	0,75
Class 3	0,60

The longitudinal joints for all classes of vessels are to be butt joints. Circumferential joints for Classes 1, 2/1 and 2/2 vessels are to be butt joints and for Class 3 vessels may be either butt joints or lap joints.

Where a pressure vessel is to be made of alloy steel and where the scantlings have been approved on the basis of the high temperature properties of the material, particulars of the electrodes to be used including typical mechanical properties and chemical composition of the deposited weld metal are to be submitted for approval.

Classification of Fusion Welded Pressure Vessels

107 For Rule purposes pressure vessels are graded as follows:—

Class 1

Pressure parts of boilers and fired pressure vessels intended for design pressures above 3,5 kg/cm^2 (50 lb/in^2). Pressure parts of steam heated steam generators where the design pressure exceeds 11,5 kg/cm^2 (165 lb/in^2), or where the design pressure, in kg/cm^2 (lb/in^2), multiplied by the internal diameter of the shell, in mm (in), exceeds 14 700 (8250).

Other pressure vessels where the shell thickness exceeds 38 mm (1·5 in).

Classes 2/1 and 2/2

Pressure parts of boilers and fired pressure vessels not included in Class 1.

Pressure parts of steam heated steam generators not included in Class 1.

Other pressure vessels where the design pressure exceeds 17,5 kg/cm^2 (250 lb/in^2), or the metal temperature exceeds 150°C (300°F), or where the design pressure, in kg/cm^2 (lb/in^2), multiplied by the actual thickness of the shell, in mm (in), exceeds 160 (90).

Maximum shell thickness 38 mm (1·5 in).

Class 3

Pressure vessels not included in Classes 1, 2/1 and 2/2.

Maximum shell thickness 16 mm (0·625 in).

Pressure vessels which may be constructed in accordance with Classes 2/1, 2/2 or 3 standards, as indicated above, will, if manufactured in accordance with the requirements of a superior class, be approved with the scantlings appropriate to that class.

In special circumstances relating to service conditions, materials, operating temperature, the carriage of dangerous gases and liquids, etc., it may be necessary to require that certain pressure vessels be manufactured in accordance with the requirements of a superior class.

Heat treatment, non-destructive and routine tests where required, for the four classes of pressure vessel are indicated in Table J 1.2 and details of these requirements are given in J 4.

TABLE J 1.2

Class	Radiographic Examination	Heat Treatment	Routine Weld Tests	Hydraulic Test
1	required *see* J 420(a)	*see* J 439	required	required
2/1	spot required *see* J 420(b)	*see* J 439	required	required
2/2	—	*see* J 439	required	required
3	—	—	—	required

Pressure Parts of Irregular Shape

108 Where pressure parts are of such irregular shape that it is impracticable to design their scantlings by the application of the formulæ in J 2, the suitability of their construction is to be determined by hydraulic proof test of a prototype or by an agreed alternative method.

General

109 Where working conditions are adverse, special consideration may require to be given to increasing the scantlings derived from the formulæ, e.g. by increasing the corrosion or other allowance at present shown in the formulæ or adopting a design pressure higher than defined in 101, so as to offset the possible reduction of life in service caused by the adverse conditions. In this connection, where necessary, account should also be taken of any excess of loading resulting from:—

(1) Impact loads, including rapidly fluctuating pressures,

(2) Weight of the vessel and normal contents under operating and test conditions,

(3) Superimposed loads such as other pressure vessels, operating equipment, insulation, corrosion-resistant or erosion-resistant linings and piping,

(4) Reactions of supporting lugs, rings, saddles or other types of supports,

(5) The effect of temperature gradients on maximum stress.

Design Symbols

110 The symbols used in the various formulæ in J 2, unless otherwise stated, are as defined below and are applicable to the specific part of the pressure vessel under consideration.

	Metric units	*(British units)*
T = minimum thickness	mm	(in)
P = design pressure	kg/cm²	(lb/in²)
D_i = inside diameter	mm	(in)
D_o = outside diameter	mm	(in)
R_i = inside radius	mm	(in)
R_o = outside radius	mm	(in)
r_i = inside knuckle radius	mm	(in)
r_o = outside knuckle radius	mm	(in)
p = pitch	mm	(in)
d = diameter of hole or opening	mm	(in)
c = corrosion allowance	mm	(in)
f = allowable stress	kg/cm²	(lb/in²)
J = joint factor applicable to welded seams, or ligament efficiency between tube holes (expressed as a fraction)	—	—
t = design temperature	°C	(°F)

Section 2

DESIGN

SEAMLESS AND FUSION WELDED CYLINDRICAL SHELLS, DRUMS AND HEADERS SUBJECT TO INTERNAL PRESSURE

Minimum Thickness

201 The minimum thickness, T, of a cylindrical shell is to be determined by the following formula:—

$$T = \frac{P R_i}{fJ - 0{,}5P} + 0{,}75 \text{ mm} \quad \left(T = \frac{P R_i}{fJ - 0{\cdot}5P} + 0{\cdot}03 \text{ in}\right)$$

where T, P, R_i and f are as defined in J 110.

J = efficiency of ligaments between tube holes or other openings in the shell or the joint factor of the longitudinal joints (expressed as a fraction). *See* J 106, 202 to 205, whichever applies. In the case of seamless shells clear of tube holes or other openings $J = 1{,}0$.

The above formula is only applicable where the resulting thickness does not exceed half the internal radius, i.e. where R_o is not greater than 1,5 R_i.

Irrespective of the thickness determined by the above formula, T is not to be less than:—

(*a*) for unfired pressure vessels 5 mm (0·197 in),

(*b*) for drum shell plates of fired pressure vessels, which are unpierced by tube holes 9,5 mm (0·375 in) (*see* Note),

(*c*) for tube plates, such thickness as may be necessary to allow a minimum parallel belt width of tube seat of 9,5 mm (0·375 in) or such greater width as may be necessary to ensure tube tightness. (*See* J 313).

NOTE:—In special cases where it is proposed to use a shell thickness less than in (*b*), the proposal will be the subject of special consideration.

Efficiency of Ligaments between Tube Holes

202 Where tube holes are drilled in a cylindrical shell in a line or lines parallel to its axis the efficiency J of the ligaments is to be determined as follows:—

(*a*) *Regular drilling.* Where the distance between adjacent tube holes is constant (*see* Fig. J 2.1)

$$J = \frac{p - d}{p} \qquad (1)$$

where p = pitch of tube holes, in mm (in),

d = the mean effective diameter of the tube holes, in mm (in), after allowing for any serrations, counterboring or recessing, or the compensating effect of the tube stub (*see* 203 and 206).

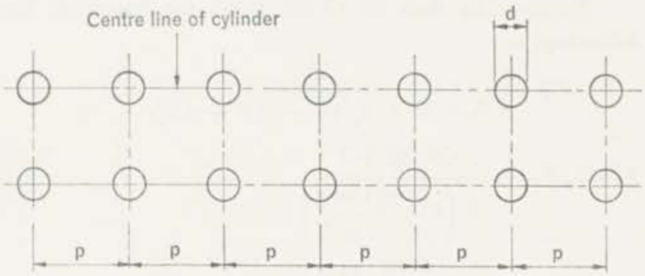


FIG. J 2.1 REGULAR DRILLING

(*b*) *Irregular drilling.* Where the distance between centres of adjacent tube holes is not constant (*see* Fig. J 2.2),

$$J = \frac{p_1 + p_2 - 2d}{p_1 + p_2} \qquad (2)$$

where p_1 = the shorter of any two adjacent pitches, in mm (in),

p_2 = the longer of any two adjacent pitches, in mm (in),

d = the mean effective diameter of the tube holes in mm (in), after allowing for any serrations, counterboring or recessing, or the compensating effect of the tube stub (*see* 203 and 206).

When applying formula (2) the double pitch (p_1+p_2) chosen is to be that which makes J a minimum and in no case is p_2 to be taken as greater than twice p_1.

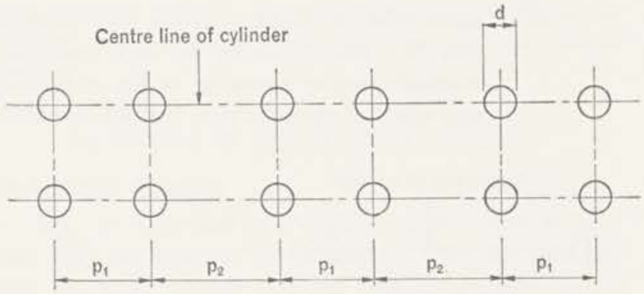


FIG. J 2.2 IRREGULAR DRILLING

Compensating Effect of Tube Stubs

203 Where a drum or header is drilled for tube stubs fitted by strength welding either in line or in staggered formation, the effective diameter of the holes is to be taken

as $$d_e = d_a - \frac{A}{T} \qquad (1)$$

where d_e = the equivalent diameter of the hole, in mm (in),

d_a = the actual diameter of the hole, in mm (in),

T = the thickness of the shell, in mm (in),

A = the compensating area provided by each tube stub and its welding fillets, in mm² (in²).

The compensating area A is to be measured in a plane through the axis of the tube stub parallel to the longitudinal axis of the drum or header and is to be calculated as follows (*see* Figs. J 2.3 and J 2.4):—

(i) The sectional area of the stub, in excess of that required by 222 for the minimum tube thickness, from the interior surface of the shell up to a distance "b" from the outer surface of the shell (*see* Notes 1 and 2);

(ii) plus the sectional area of the stub projecting inside the shell within a distance "b" from the inner surface of the shell (*see* Note 2);

(iii) plus the sectional area of the welding fillets inside and outside the shell:—

where $$b = \sqrt{d_a t_a} \qquad (2)$$

t_a = actual thickness of the tube stub, in mm (in).

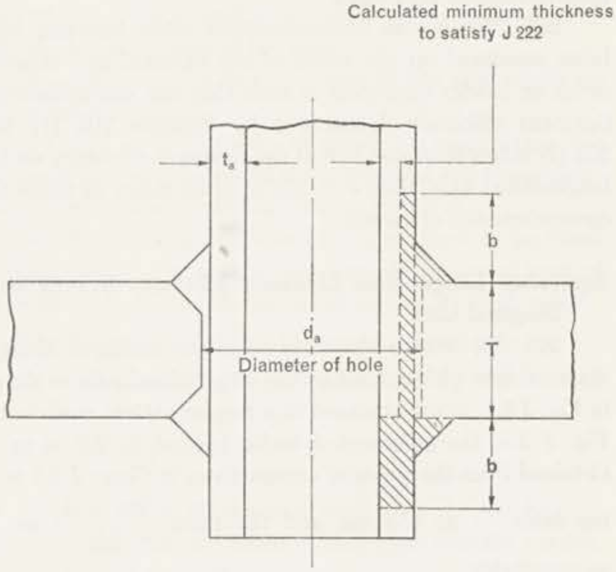


FIG. J 2.3 COMPENSATION OF WELDED TUBE STUBS

Area A equals twice the area shown cross-hatched

NOTE 1.—In the case of a set-on stub (*see* Fig. J 2.4) the compensation extends from the outer surface of the shell only.

NOTE 2.—Where the material of the tube stub has an allowable stress different from that of the shell the compensating sectional area of the stub is to be multiplied by the ratio:—

$$\frac{\text{allowable stress of stub at design metal temperature}}{\text{allowable stress of shell at design metal temperature}}$$

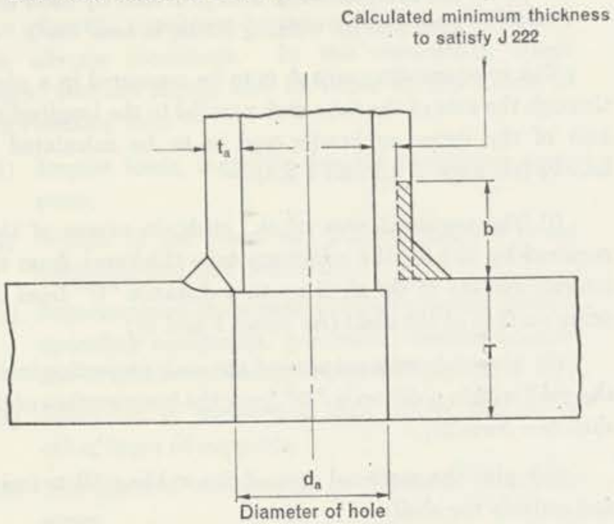


FIG. J 2.4 COMPENSATION OF WELDED TUBE STUBS

Area A equals twice the area shown cross-hatched

Circumferential Ligaments

204 Where the circumferential pitch between tube holes measured on the mean of the external and internal drum or header diameters is such that the circumferential ligament efficiency determined by formulæ 202 (1) and 202 (2) is less than one half of the ligament efficiency on the longitudinal axis, then J in 201 is to be taken as twice the circumferential efficiency.

Equivalent Longitudinal Ligament Efficiency Drilling on a Diagonal Line

205 (*a*) Where the tube holes are arranged along a diagonal line with respect to the longitudinal axis as shown in Fig. J 2.5, or are arranged in a regular pattern as shown in Fig. J 2.6, the efficiency J to be applied in 201 is to be obtained from the series of curves given in Chart J 2.1 with the ratio $\frac{b}{a}$ as abscissa and the ratio $\frac{2a-d}{2a}$ or $\frac{d}{a}$ as parameter

where a and b as shown in Figs. J 2.5 and J 2.6, are measured in mm (in) on the median line of the plate.

d = mean effective diameter of the tube holes, in mm (in), after allowing for any serrations, counterboring or recessing, or the compensating effect of the tube stub (*see* 203 and 206).

NOTE.—The data on Chart J 2.1 are based on the following:—

$$J = \frac{2}{A + B + \sqrt{(A-B)^2 + 4C^2}}$$

where $A = \dfrac{\cos^2\alpha + 1}{2\left(1 - \dfrac{d\cos\alpha}{a}\right)}$

$$B = 0{,}5\left(1 - \frac{d\cos\alpha}{a}\right)(\sin^2\alpha + 1)$$

$$C = \frac{\sin\alpha\cos\alpha}{2\left(1 - \dfrac{d\cos\alpha}{a}\right)}$$

$$\cos\alpha = \frac{1}{\sqrt{1 + \dfrac{b^2}{a^2}}}$$

$$\sin\alpha = \frac{1}{\sqrt{1 + \dfrac{a^2}{b^2}}}$$

where α = angle of centre line of cylinder to centre line of diagonal holes.

(*b*) Where there is regular staggered spacing of tube holes as shown in Fig. J 2.7, the smallest value of the efficiency J of all ligaments (longitudinal, circumferential and diagonal) is obtained from Chart J 2.2 with the ratio $\frac{b}{a}$ as abscissa and the ratio $\frac{2a-d}{2a}$ or $\frac{d}{a}$ as parameter

where a and b as shown in Fig. J 2.7 are measured, in mm (in), on the median line of the plate,

d = mean effective diameter of the tube holes, in mm (in), after allowing for any serrations, counterboring or recessing, or the compensating effect of the tube stub (*see* 203 and 206).

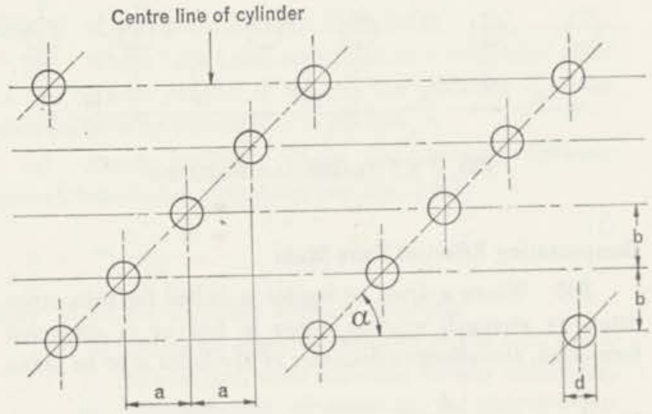


FIG. J 2.5 SPACING OF HOLES ON A DIAGONAL LINE

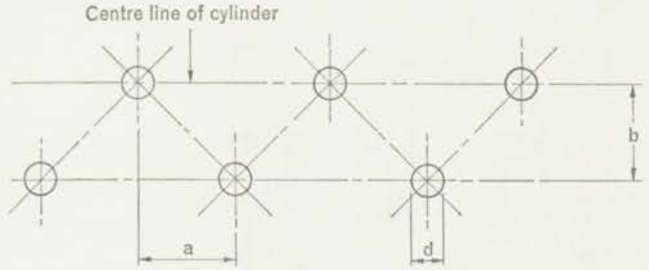


FIG. J 2.6 REGULAR SAW-TOOTH PATTERN OF HOLES

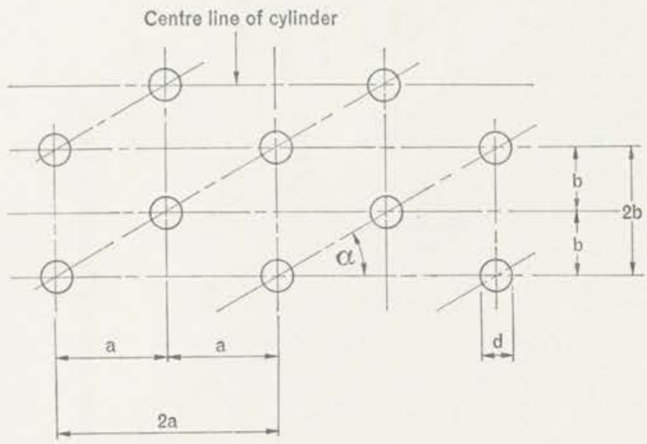


FIG. J 2.7 REGULAR STAGGERING OF HOLES

(*c*) Where tube holes are irregularly spaced along a drum or header, and do not come in a straight line, the formula 202 (2) is to apply except that an equivalent longitudinal width of the diagonal ligament is to be used. An equivalent longitudinal width is that width which gives, using formula 202 (1), the same efficiency as would be obtained using Chart J 2.1 for the diagonal ligament in question.

OPENINGS IN CYLINDRICAL SHELLS

Unreinforced Openings

206 (*a*) Openings in a definite pattern such as tube holes may be designed in accordance with the rules for ligaments in 202 to 205 provided that the diameter of the largest hole in the group does not exceed that permitted by (*b*) below.

(*b*) The maximum diameter "d" of any unreinforced opening is to be obtained from the curves in Chart J 2.3 or J 2.4.

In the Charts the value of K to be used is calculated from the following formula:—

$$K = \frac{P\,D_o}{1{,}82\,f\,T}$$

where P, D_o and f are as defined in J 110,

T = actual thickness of shell, in mm (in).

For elliptical or oval holes "d" refers to the mean of the major and minor axes.

No unreinforced opening is to exceed 200 mm (7·875 in) in diameter.

Reinforced Openings

207 Openings larger than those permitted by 206 are to be reinforced by the method shown in Fig. J 2.8. Compensation shall be considered adequate when the compensating area Y, Figs. J 2.8a and J 2.8b is equal to or greater than the area X requiring compensation.

Area X is to be calculated as the product of the inside radius of the standpipe and the thickness A which would be required for an equivalent seamless unpierced shell.

Area Y is to be measured in a plane through the axis of the standpipe parallel to the longitudinal axis of the drum and is to be calculated as follows:—

(i) For that part of the standpipe which projects outside the shell calculate the full sectional area of the stem up to a distance C from the actual outer surface of the shell plate and deduct from it the sectional area which the stem would have if its thickness were as calculated in accordance with 222.

(ii) Add to it the full sectional area of that part of the stem which projects inside the shell up to a distance C from the inside surface of the shell.

(iii) Add to it the sectional area of the fillet welds on both sides of the shell.

(iv) Add to it the area obtained by multiplying the difference between the actual shell thickness and the equivalent unpierced shell thickness A by a length D.

(v) If additional reinforcement is required to be fitted as illustrated in Fig. J 2.8b add also the sectional area of the reinforcement and the sectional area of its fillet welds.

The following notations are used in Fig. J 2.8:—

C in mm (in) is the lesser of 2,5 T_a
or $2{,}5\,t_a + t_r$

D in mm (in) is the greater of 0,5 d
or $T_a + 75$ mm ($T_a + 3$ in)

T_a = actual thickness of shell plate, in mm (in),

t_a = actual thickness of standpipe stem or branch, in mm (in),

t_r = thickness of added reinforcement, in mm (in), (t_r will be zero when there is no compensating plate on the side of the shell under consideration),

d = internal diameter of standpipe or branch, in mm (in).

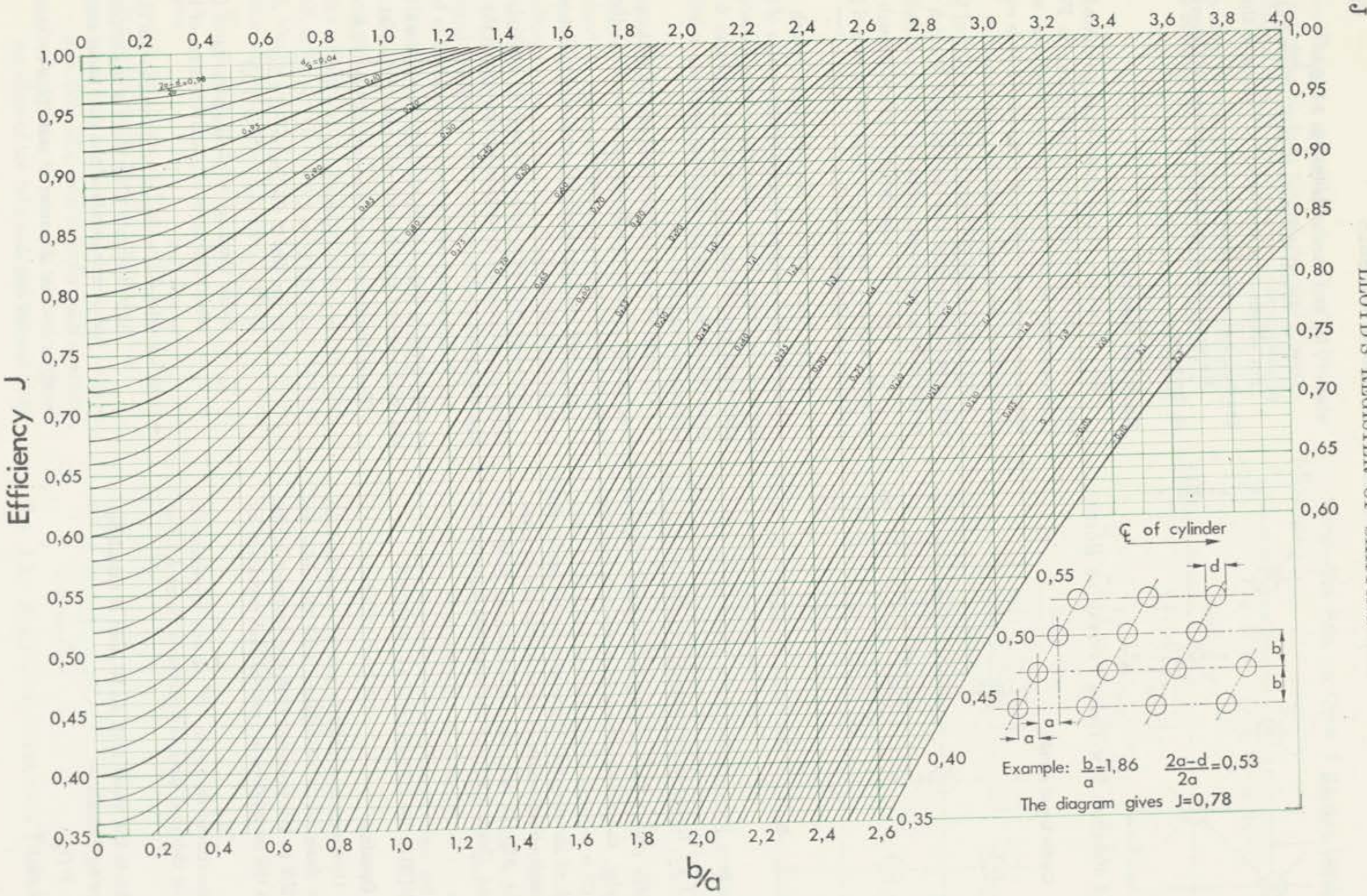


CHART J 2.1 EFFICIENCY OF LIGAMENT ALONG A DIAGONAL LINE

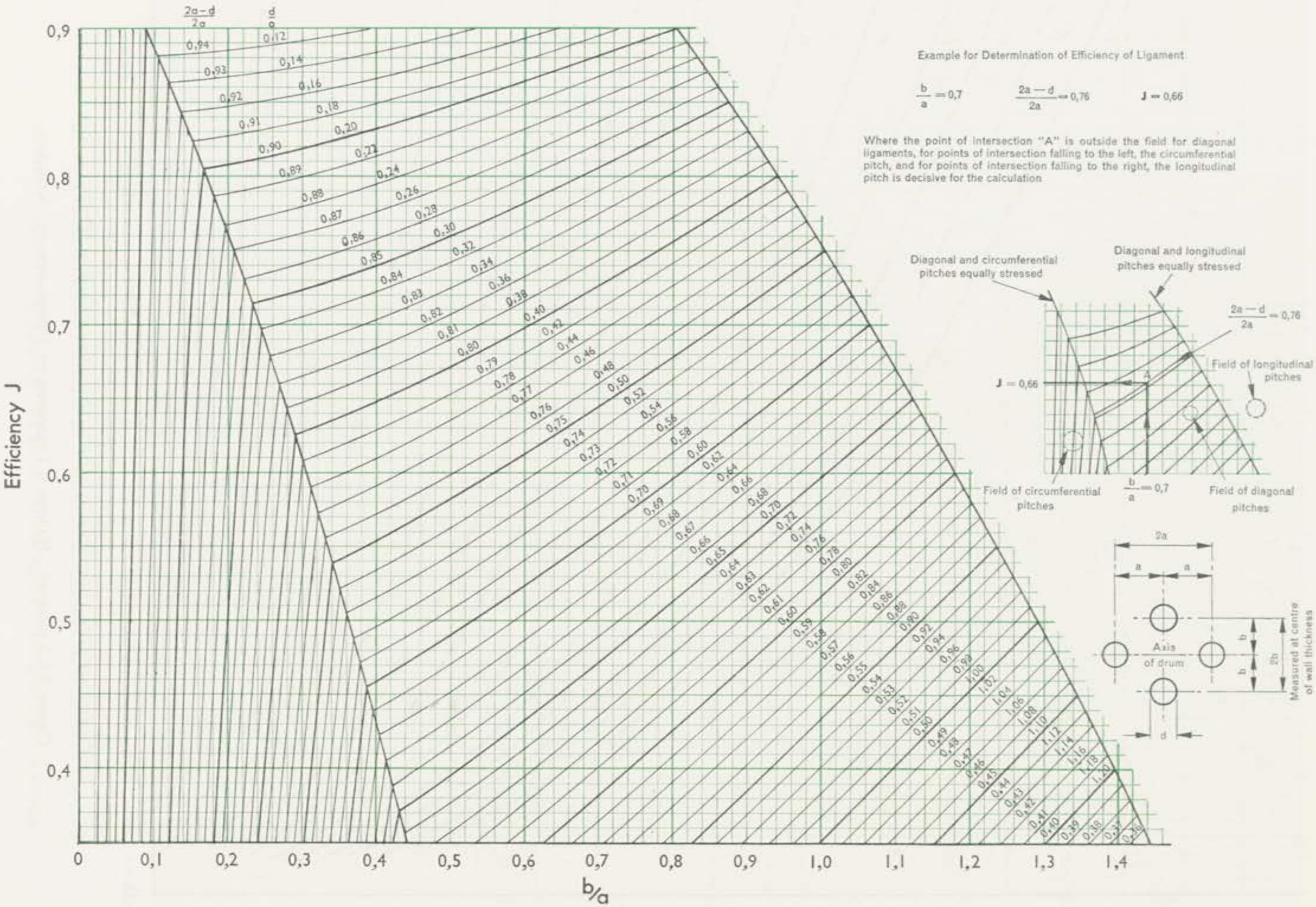


Chart J 2.2 Efficiency of Ligaments between Holes

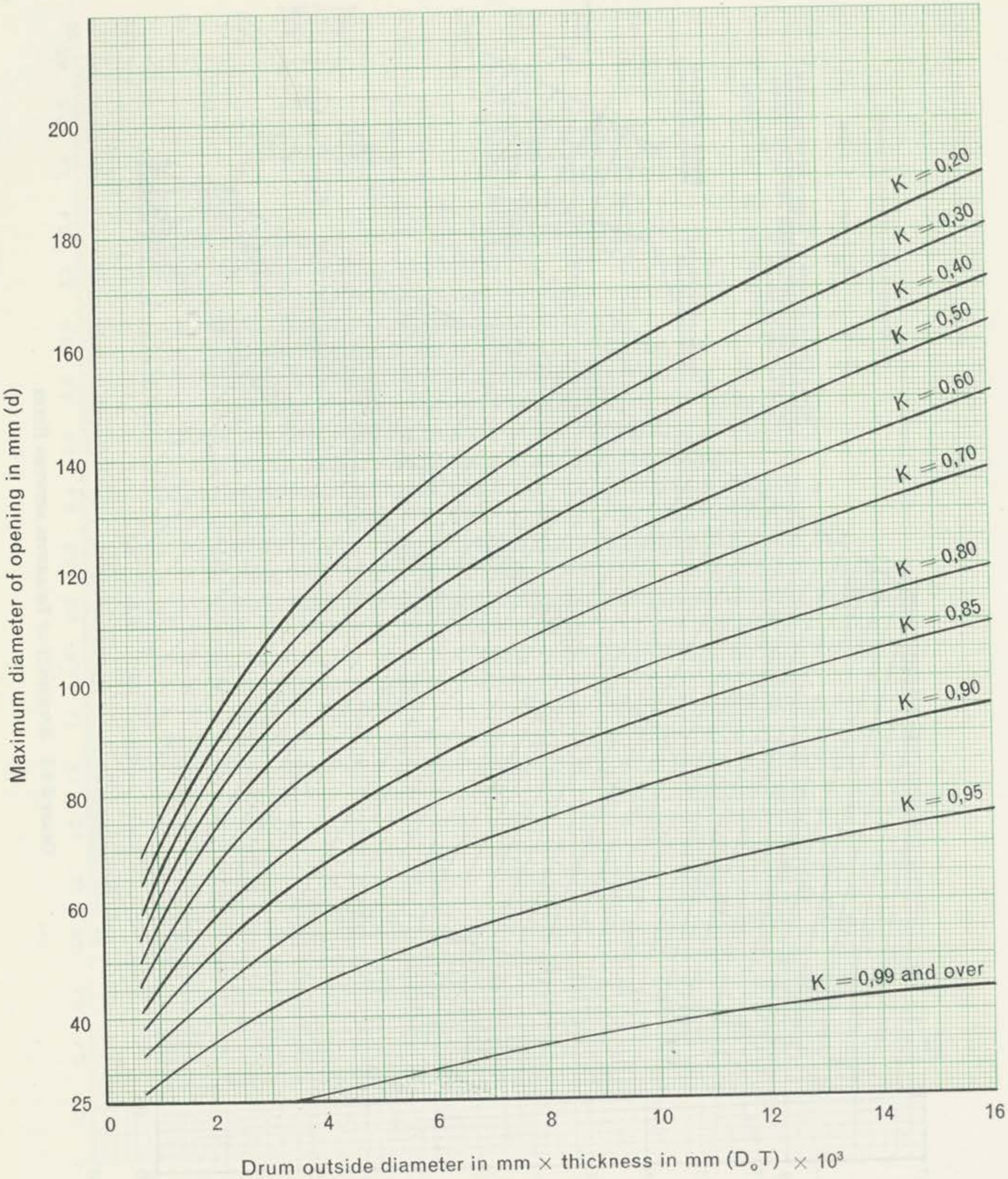


CHART J 2.3 (Metric) MAXIMUM DIAMETER OF UNREINFORCED OPENINGS

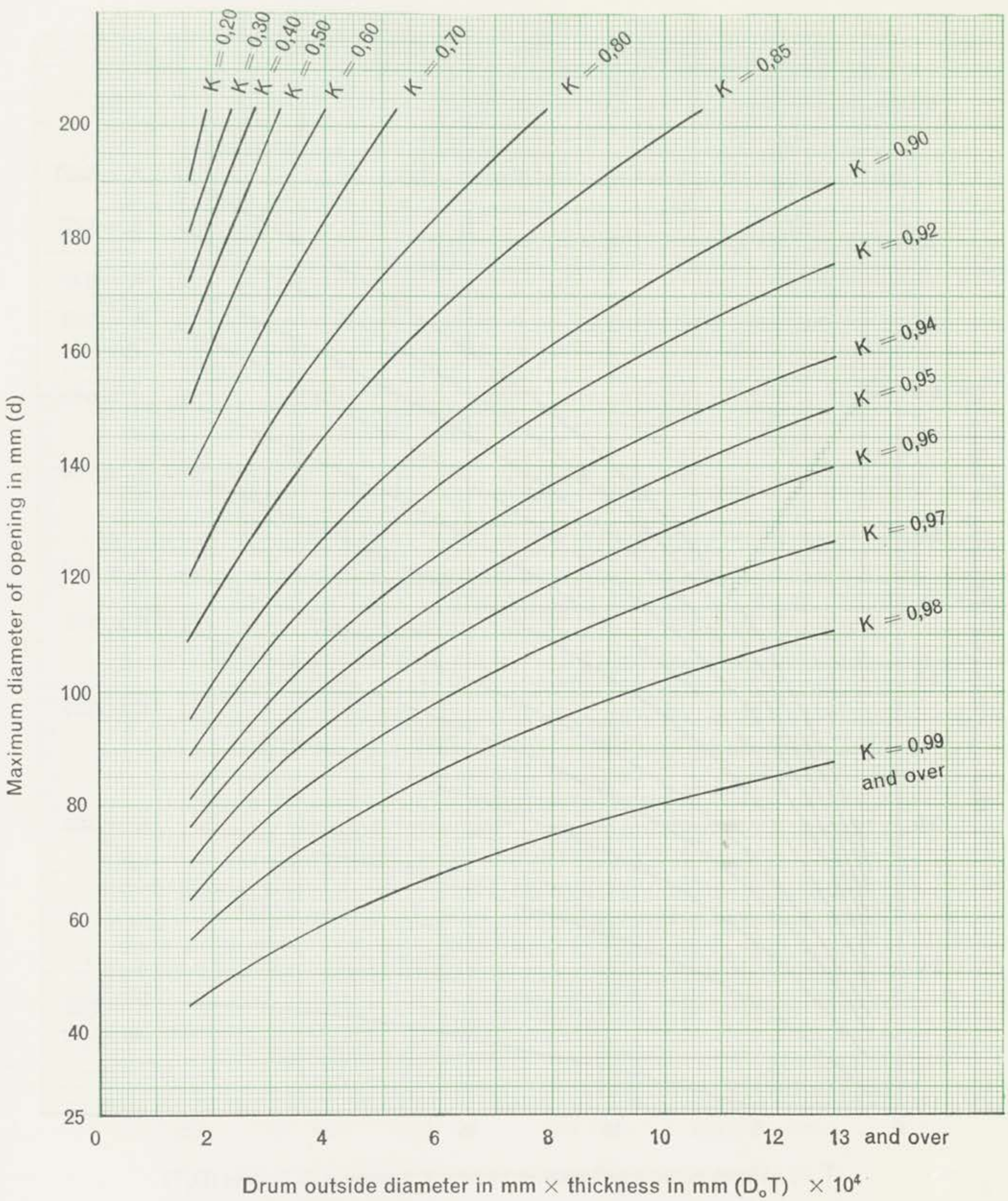


CHART J 2.4 (Metric) MAXIMUM DIAMETER OF UNREINFORCED OPENINGS

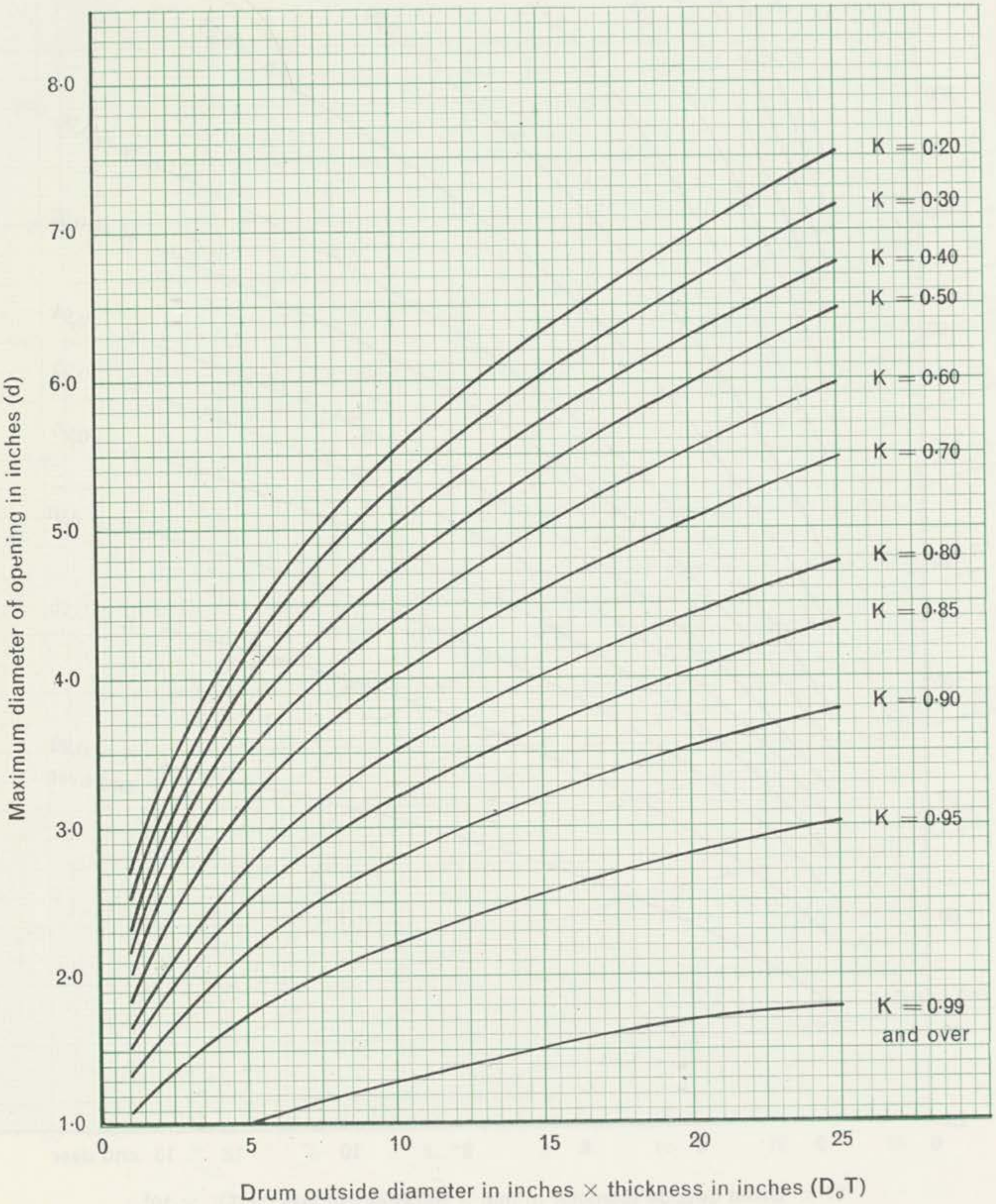


CHART J 2.3 (British) MAXIMUM DIAMETER OF UNREINFORCED OPENINGS

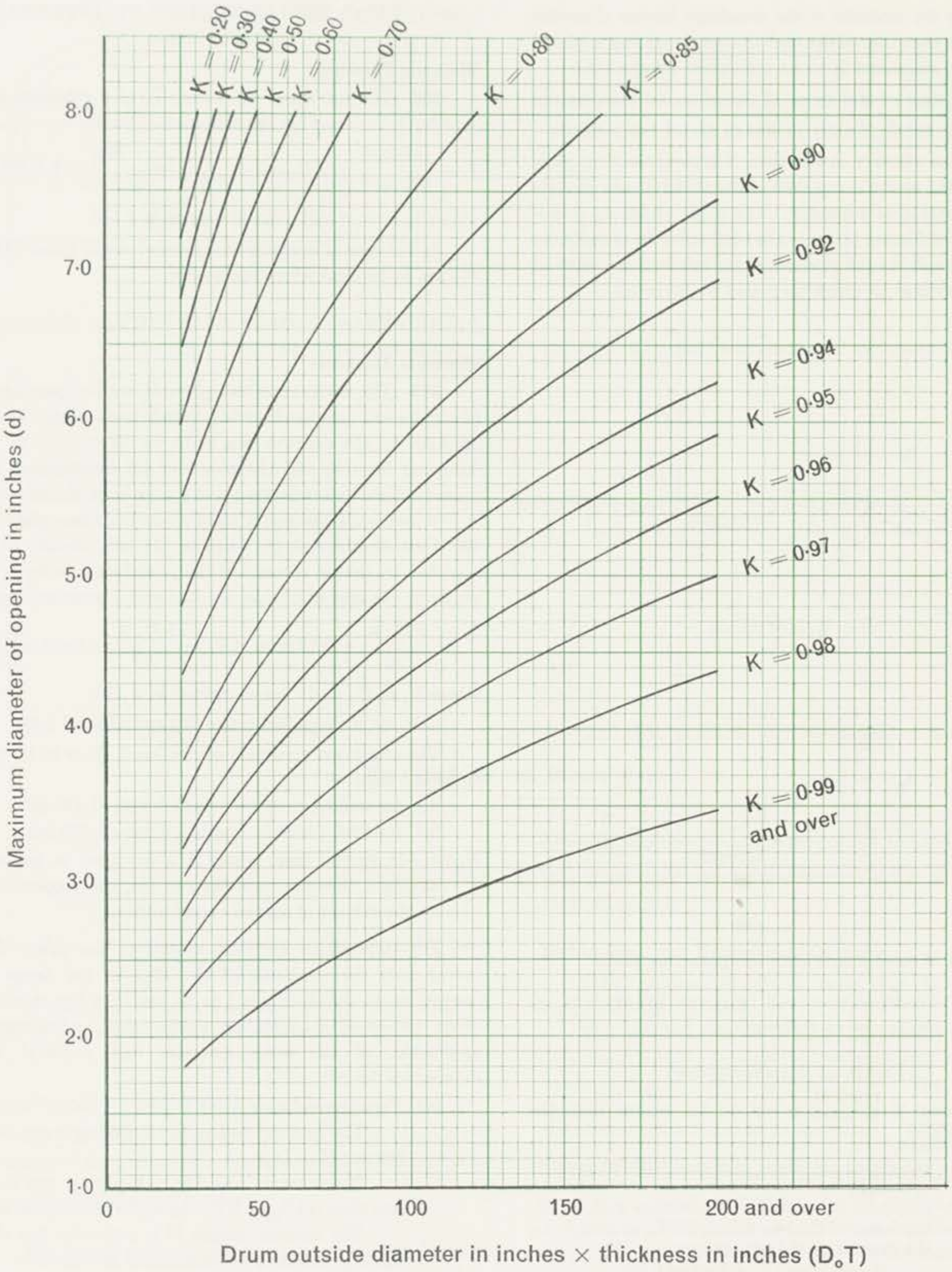
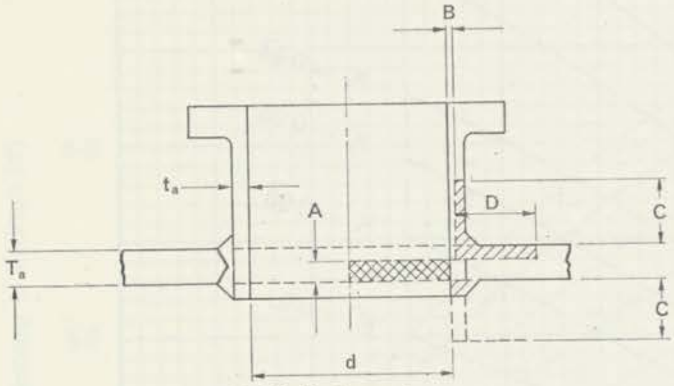


CHART J 2.4 (British) MAXIMUM DIAMETER OF UNREINFORCED OPENINGS

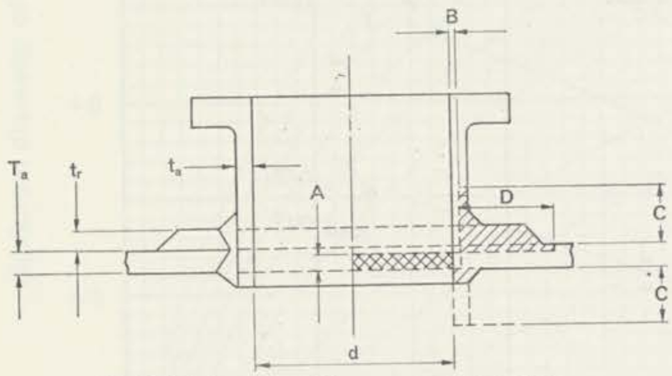
Where the material of the standpipe has an allowable stress lower than that of the shell the compensating sectional area of the standpipe is to be multiplied by the ratio

$$\frac{\text{allowable stress of standpipe at design metal temperature}}{\text{allowable stress of shell at design metal temperature}}$$

In cases where Y is less than X a compensating plate is to be fitted to the drum shell at the standpipe to provide the additional area necessary. The welds attaching standpipes and reinforcing plates to the shell are to be of sufficient size to transmit the full strength of the reinforcing areas and all other loadings to which they may be subjected.



(*a*) Welded nozzle



(*b*) Welded nozzle with compensating plate

FIG. J 2.8 COMPENSATION FOR WELDED STANDPIPES OR BRANCHES IN CYLINDRICAL SHELLS.

LIMITS OF REINFORCEMENT

The area Y is not to be weaker than the area X.

where A = calculated thickness of a shell without joint or opening,

B = thickness calculated in accordance with J 222.

C = the lesser of the two values, $2{,}5\mathsf{T_a}$ or $2{,}5t_a + t_r$,

D = the greater of the two values: $\mathsf{T_a}$+75mm ($\mathsf{T_a}$+3 in) or $0{,}5\mathsf{d}$.

Note: t_r shall be equal to zero when there is no compensating plate on the side of the shell under consideration.

SPHERICAL SHELLS SUBJECT TO INTERNAL PRESSURE

Minimum Thickness

208 The minimum thickness, T, of a spherical shell is to be determined by the following formula:—

$$\mathsf{T} = \frac{\mathsf{PR_i}}{2\mathsf{fJ} - \mathsf{P}} + 0{,}75 \text{ mm} \qquad \left(\mathsf{T} = \frac{\mathsf{PR_i}}{2\mathsf{fJ} - \mathsf{P}} + 0{\cdot}03 \text{ in}\right)$$

where T, P, $\mathsf{R_i}$, f and J are as defined in J 110.

In the case of openings in spherical shells, paras 211 to 214 are to be used where applicable.

DISHED ENDS SUBJECT TO INTERNAL PRESSURE

Minimum Thickness

209 The thickness of torispherical, semi-ellipsoidal and hemispherical unstayed ends, dished from plate, having pressure on the concave side is to be determined by the following formula and the shape of (*a*) torispherical and (*b*) semi-ellipsoidal ends is to be within the limits stated below.

Where ends are made from more than one plate the thickness determined by formula (1) will require to be modified by taking account of the joint factor between the plates in the case of Classes 2/1, 2/2 and 3 pressure vessels.

$$\mathsf{T} = \frac{\mathsf{P\,D_o\,K}}{2\mathsf{f}} + 0{,}75 \text{ mm} \quad \left(\mathsf{T} = \frac{\mathsf{P\,D_o\,K}}{2\mathsf{f}} + 0{\cdot}03 \text{ in}\right) \qquad (1)$$

where T, P, $\mathsf{D_o}$ and f are as defined in J 110,

K = a shape factor (*see* 210 and Chart J 2.5).

The minimum thickness of the head, T, is in no case to be less than:—

(i) for unfired pressure vessels 5 mm (0·197 in).

(ii) for fired pressure vessels 9,5 mm (0·375 in).

NOTE:—In special cases where it is proposed to use ends having a thickness less than in (ii), the proposal will be the subject of special consideration.

For ends which are butt welded to the drum shell (*see* J 106) the thickness of the edge of the flange for connection to the shell is not to be less than the thickness of an unpierced seamless or welded shell, whichever is applicable, of the same diameter and material and determined by 201.

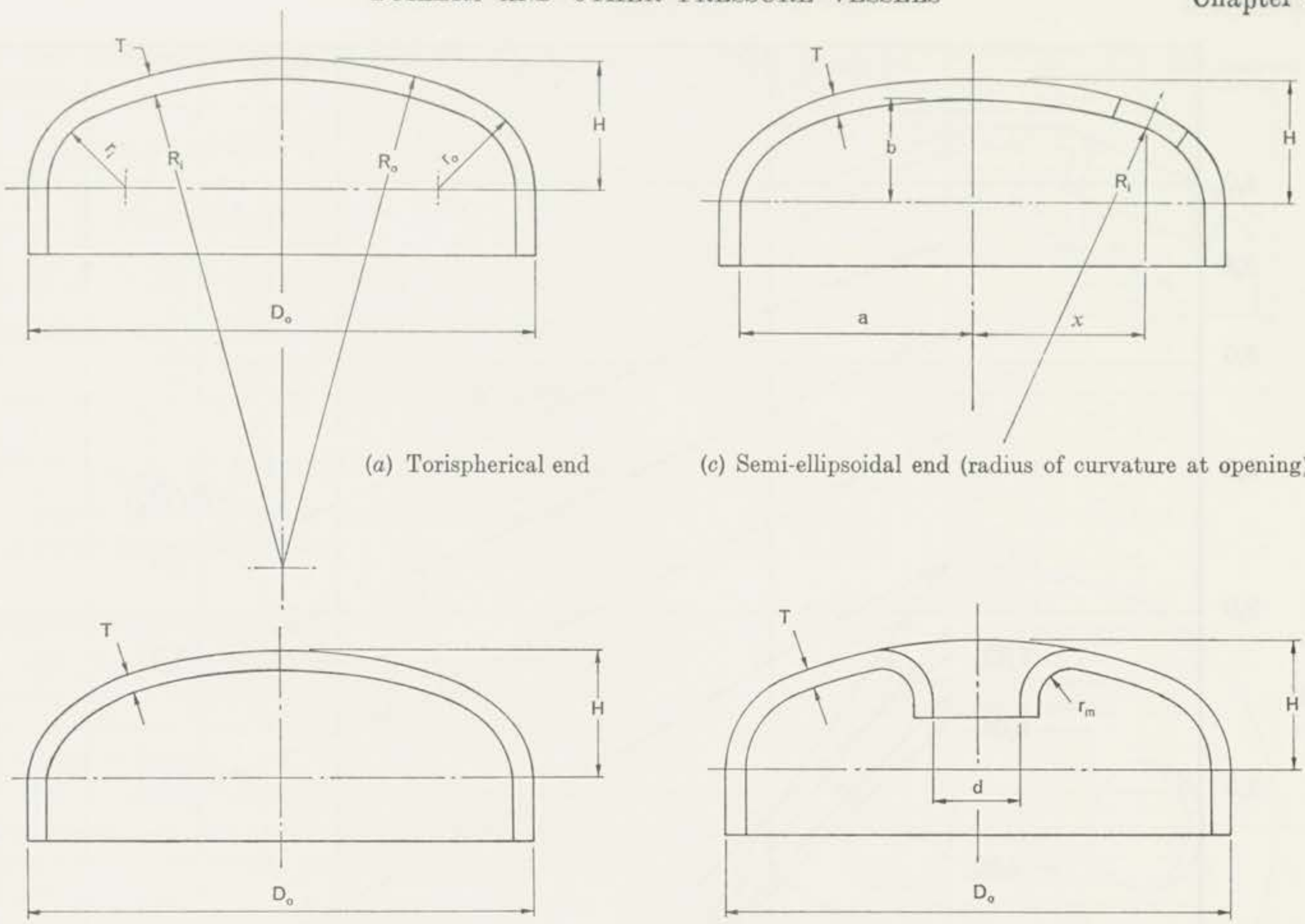
(*a*) *Torispherical ends*

The internal radius $\mathsf{R_i}$ of dishing is not to be greater than $\mathsf{D_o}$.

The internal knuckle radius $\mathsf{r_i}$ is not to be less than $0{,}1\mathsf{D_o}$ or $3\mathsf{T}$, whichever is the greater.

The external height H is not to be less than $0{,}18\mathsf{D_o}$, and is to be determined as follows:—

$$\mathsf{H} = \mathsf{R_o} - \sqrt{(\mathsf{R_o} - 0{,}5\,\mathsf{D_o})\,(\mathsf{R_o} + 0{,}5\,\mathsf{D_o} - 2\,\mathsf{r_o})} \qquad (2)$$



(*a*) Torispherical end

(*b*) Semi-ellipsoidal end

(*c*) Semi-ellipsoidal end (radius of curvature at opening)

(*d*) End with manhole (semi-ellipsoidal or torispherical)

FIG. J 2.9 TYPICAL DISHED ENDS

(*b*) *Semi-Ellipsoidal ends*

The external height H is not to be less than $0{,}2D_O$

where D_O = the external diameter of the parallel portion of the end, in mm (in),

In both cases H is to be measured from the commencement of curvature (*see* Fig. J 2.9).

Shape Factors for Dished Ends

210 The shape factor K to be used in 209, formula (1), is obtained from the curves in Chart J 2.5 and depends on the ratio of height to diameter $\frac{H}{D_O}$.

The lowest curve in the series provides the factor K for plain (i.e. unpierced) ends. Where the value $\frac{H}{D_O}$ is lower than 0,25 the value of K depends on the ratio of thickness to diameter $\frac{T}{D_O}$ as well as on the ratio $\frac{H}{D_O}$ and a trial calculation may be necessary to arrive at the correct value of K.

Dished Ends with Unreinforced Openings

211 Openings in dished ends may be circular or approximately elliptical.

The upper curves on Chart J 2.5 provide values of K to be used in 209, formula (1), for ends with unreinforced openings (e.g. manholes or tube holes). The selection of the correct curve depends on the value $\frac{d}{\sqrt{D_O T}}$

where d = the diameter of the largest opening in the end plate, in mm (in), (in the case of an elliptical opening, the larger axis of the ellipse),

T = minimum thickness, after dishing, in mm (in),

D_O = outside diameter of dished end, in mm (in).

Trial calculation is necessary in order to select the correct curve.

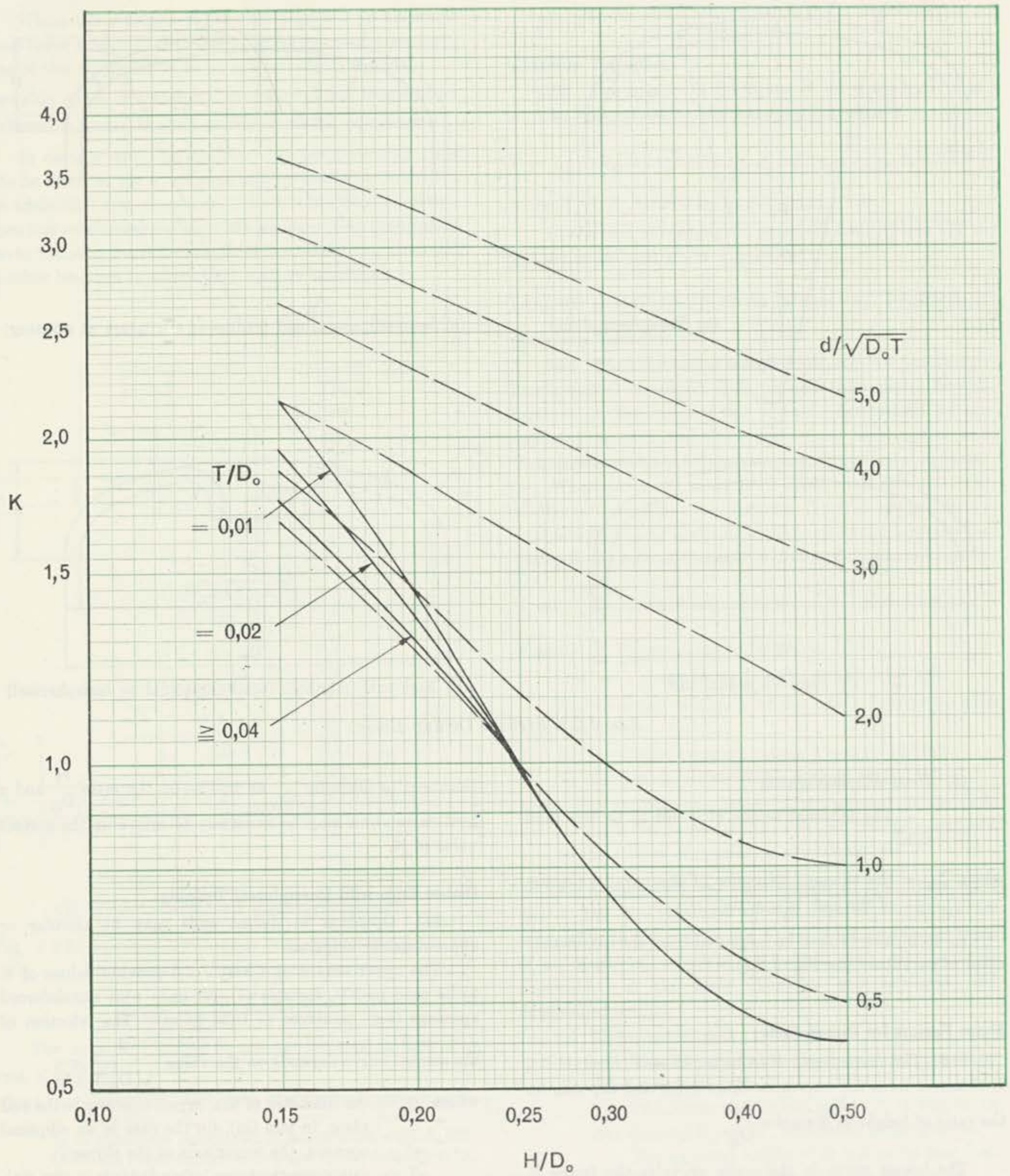


CHART J 2.5 SHAPE FACTOR

The following requirements must in any case be satisfied:—

$\frac{T}{D_o}$ is not to exceed 0,1

$\frac{d}{D_o}$ is not to exceed 0,7.

NOTE.—It will be seen from Chart J 2.5 that for any selected ratio of $\frac{H}{D_o}$, the curve for unpierced ends indicates a value for $\frac{d}{\sqrt{D_o T}}$ as well as for K. Holes giving a value of $\frac{d}{\sqrt{D_o T}}$ not greater than the value so obtained may thus be pierced through an end designed as unpierced without any increase in thickness.

Flanged Openings in Dished Ends

212 The requirements in 211 apply equally to flanged openings and to unflanged openings cut in the plate of an end. No reduction may be made in end plate thickness on account of flanging.

Where openings are flanged the radius r_m of the flanging is not to be less than 25 mm (1 in) (*see* Fig. J 2.9d). The thickness of the flanged portion may be less than the calculated thickness T.

Location of Unreinforced and Flanged Openings in Dished Ends

213 Unreinforced and flanged openings in dished ends are to be so arranged that the distance from the edge of the hole to the outside edge of the plate and the distance between openings are not less than those shown in Fig. J 2.10. In Fig. J 2.10, d_2 is equal to the diameter of the smaller hole.

Dished Ends with Reinforced Openings

214 Where it is desired to use a large opening on a dished end of less thickness than would be required by the application of 211 reinforcement of the end is to be provided.

Reinforcement may consist of a ring or standpipe welded into the hole, or of reinforcing plates welded to the outside and/or inside of the end in the vicinity of the hole, or a combination of both methods (*see* Fig. J 2.11). Forged reinforcements may be used.

Reinforcing material within the following limits may be taken as effective reinforcement.

(*a*) The effective width l_1 of reinforcement is not to exceed $\sqrt{2 R_i T}$ or $0{,}5 d_o$ whichever is the lesser.

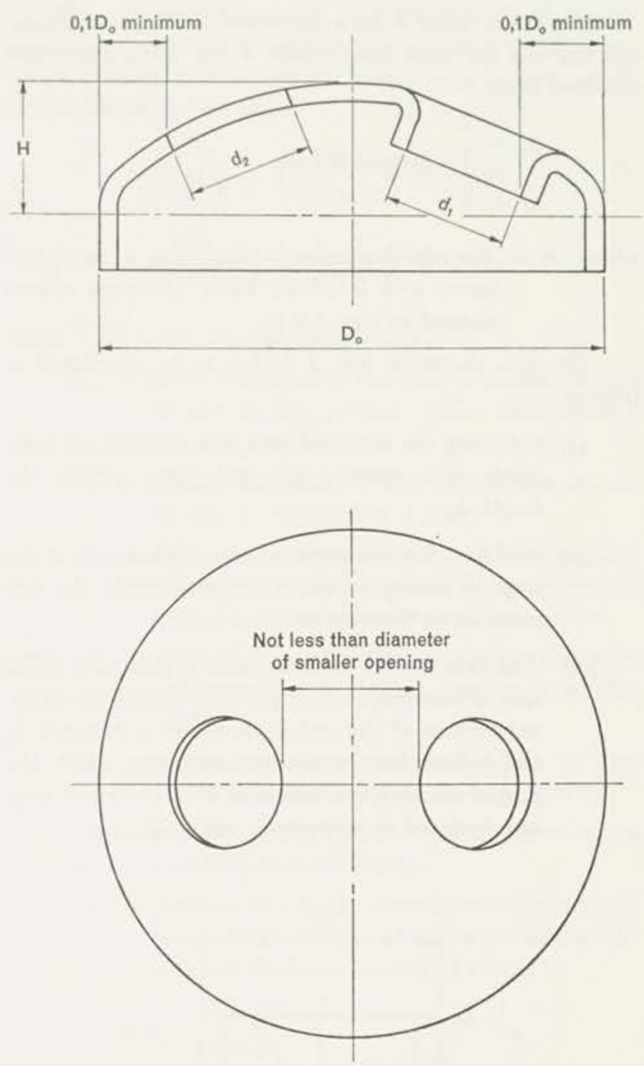


FIG. J 2.10 OPENINGS IN DISHED ENDS

(*b*) The effective length l_2 of a reinforcing ring is not to exceed $\sqrt{d_o t_a}$

where R_i = the internal radius of the spherical part of a torispherical end, in mm (in),

or for a semi-elliptical end, the internal radius of the meridian of the ellipse at the centre of the opening, in mm (in) (*see* Note),

t_a = actual thickness of the ring or standpipe, in mm (in),

d_o = external diameter of the ring or standpipe, in mm (in).

The dimensions l_1 and l_2 are shown in Fig. J 2.11.

The shape factor K for a dished end having a reinforced opening can be read from Chart J 2.5 using the value obtained from:—

$$\frac{d_o - \frac{A}{T}}{\sqrt{D_o T}} \quad \text{instead of from} \quad \frac{d}{\sqrt{D_o T}}$$

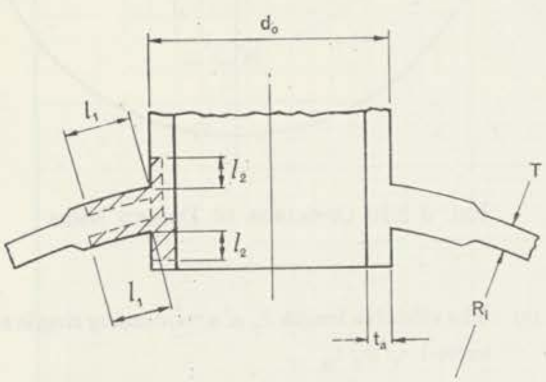
where A = the effective cross-sectional area of reinforcement and is to be twice the area shown shaded on Fig. J 2.11.

The area shown in Fig. J 2.11 is to be calculated as follows:—

(i) Calculate the sectional area of reinforcement both inside and outside the end plate within the length l_1.

(ii) Add to it the full sectional area of that part of the ring or standpipe which projects inside the end plate up to the distance l_2.

(iii) Add to it the full sectional area of that part of the ring or standpipe which projects outside the internal surface of the end plate up to a distance l_2 and deduct from it the sectional area which the ring or standpipe would have if its thickness were as calculated in accordance with 222.



$l_1 = \sqrt{2R_iT}$ or $0{,}5d_o$ whichever is the lesser

l_2 shall not exceed $\sqrt{d_o t_a}$.

Fig. J 2.11 Limits of Reinforcement

If the material of the ring or the reinforcing plates has an allowable stress lower than that of the end plate then the effective cross-section A must be reduced below that calculated in proportion to the difference in the allowable stresses for the materials.

As in 211 trial calculation is necessary in order to select the correct curve.

Note.—For the internal radius, R_i, of the meridian of the ellipse at the centre of the opening (*see* Fig. J 2.9c):—

$$R_i = \frac{\left[a^4 - x^2(a^2 - b^2)\right]^{\frac{3}{2}}}{a^4 b}$$

DISHED ENDS RESTRICTED TO CLASS 3 PRESSURE VESSELS ONLY

Minimum Thickness

215 The minimum thickness, T, of a torispherical unstayed end dished from plate and having pressure on the concave or convex side is to be determined by the following formula:—

$$T = \frac{P R_i}{C S}$$

where T, P and R_i are as defined in J 110,

C = 25,7 (576) for ends concave to pressure,

C = 16,5 (370) for ends convex to pressure,

S = specified minimum tensile strength of plate, in kg/mm² (ton/in²), which should be not less than 42 kg/mm² (26·7 ton/in²).

The inside radius of curvature, R_i, of the end plate is not to be greater than the external diameter of the cylinder to which it is attached.

The inside knuckle radius, r_i, of the arc joining the cylindrical flange to the spherical surface of the end is not to be less than four times the thickness of the end plate and in no case less than 65 mm (2·5 in).

Ends convex to pressure are not to be used for vessels exceeding 610 mm (24 in) internal diameter.

Where the end is provided with a flanged manhole the thickness of the end, in mm (in), determined by the foregoing formula is to be increased by 3 mm (0·125 in) and the total depth H of the manhole flange, measured from the outer surface of the plate on the minor axis is not to be less than

$$H = \sqrt{T_1 W}$$

where H = depth of flange, in mm (in),

T_1 = required thickness of the plate, in mm (in),

W = minor axis of the manhole, in mm (in).

CONICAL ENDS SUBJECT TO INTERNAL PRESSURE

General

216 Conical ends and conical reducing sections as shown in Fig. J 2.12 are to be designed in accordance with the equations given in 217.

Connections between cylindrical shell and conical sections and ends shall preferably be by means of a knuckle transition radius. Typical permitted details are shown in Fig. J 2.12. Alternatively, conical sections and ends may be butt-welded to cylinders without a knuckle radius when the change in angle of slope ψ between the two sections under consideration does not exceed 30°.

Conical ends may be constructed of several ring sections of decreasing thickness as determined by the corresponding decreasing diameter.

Minimum Thickness

217 The minimum thickness, T, of the cylinder, knuckle and conical section at the junction and within the distance L from the junction is to be determined by the following formula:—

$$T = \frac{P\,D_O\,K}{2\,f\,J} + 0{,}75 \text{ mm} \qquad (1)$$

$$\left(T = \frac{P\,D_O\,K}{2\,f\,J} + 0{\cdot}03 \text{ in}\right)$$

If the distance of a circumferential seam from the knuckle or junction is not less than L then J is to be taken as 1,0, otherwise J is to be the weld joint factor appropriate to the circumferential seam.

In the event of the thickness T determined by formula (2) being greater than that obtained using formula (1), the greater of the two thicknesses is to apply.

The minimum thickness T of those parts of conical sections not less than a distance L away from the junction with a cylinder or other conical section is to be determined by the following formula:—

$$T = \frac{P\,D_C}{(2\,f\,J - P)}\left(\frac{1}{\cos\alpha}\right) + 0{,}75 \text{ mm} \qquad (2)$$

$$\left(T = \frac{P\,D_C}{(2\,f\,J - P)}\left(\frac{1}{\cos\alpha}\right) + 0{\cdot}03 \text{ in}\right)$$

where T, P, f and J are as defined in J 110,

D_C = inside diameter, in mm (in), of conical section or end at the position under consideration (*see* Fig. J 2.12),

D_O = outside diameter, in mm (in), of the conical section or end (*see* Fig. J 2.12),

r_i = inside radius of transition knuckle, in mm (in), which is to be taken as 0,01 D_C in the case of conical sections without knuckle transition,

$\alpha, \alpha 1, \alpha 2$ = angle of slope of conical section (at the point under consideration) to the vessel axis (*see* Fig. J 2.12),

ψ = difference between angle of slope of two adjoining conical sections (*see* Fig. J 2.12),

K = a factor, taking into account the stress in the knuckle (*see* Table J 2.1),

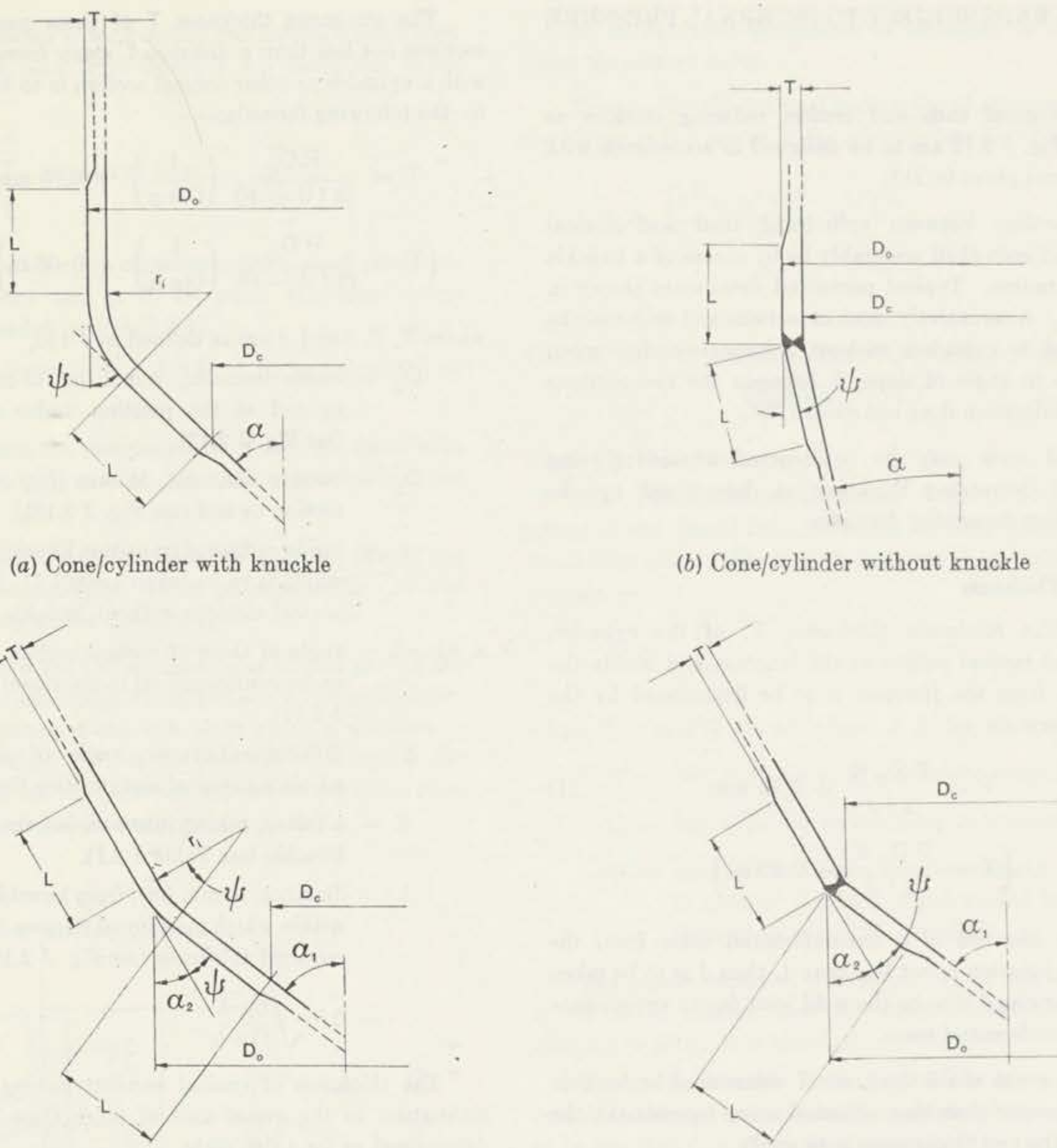
L = distance, in mm (in), from knuckle or junction within which meridional stresses determine the required thickness (*see* Fig. J 2.12),

$$= 0{,}5\sqrt{\frac{D_O\,T}{\cos\psi}}$$

The thickness of conical sections having an angle of inclination to the vessel axis of more than 75° is to be determined as for a flat plate.

TABLE J 2.1 VALUES OF K AS A FUNCTION OF ψ AND r_i/D_O

ψ	Values of K for r_i/D_O ratios of											
	0,01	0,02	0,03	0,04	0,06	0,08	0,10	0,15	0,20	0,30	0,40	0,50
10°	0,70	0,65	0,60	0,60	0,55	0,55	0,55	0,55	0,55	0,55	0,55	0,55
20°	1,00	0,90	0,85	0,80	0,70	0,65	0,60	0,55	0,55	0,55	0,55	0,55
30°	1,35	1,20	1,10	1,00	0,90	0,85	0,80	0,70	0,65	0,55	0,55	0,55
45°	2,05	1,85	1,65	1,50	1,30	1,20	1,10	0,95	0,90	0,70	0,55	0,55
60°	3,20	2,85	2,55	2,35	2,00	1,75	1,60	1,40	1,25	1,00	0,70	0,55
75°	6,80	5,85	5,35	4,75	3,85	3,50	3,15	2,70	2,40	1,55	1,00	0,55



(*a*) Cone/cylinder with knuckle

(*b*) Cone/cylinder without knuckle

(*c*) Cone/cone with knuckle

(*d*) Cone/cone without knuckle

FIG. J 2.12

STANDPIPES AND BRANCHES

Minimum Thickness

218 The minimum wall thickness of standpipes and branches is not to be less than that determined by 222 making such additions as may be necessary on account of bending, static loads and vibration.

The wall thickness, however, is not to be less than:—

$$T = 0{,}04\,D_O + 2{,}5\ \text{mm} \quad (T = 0{\cdot}04\,D_O + 0{\cdot}1\ \text{in})$$

where T and D_O are as defined in J 110.

In no case need the wall thickness exceed that of the shell.

Where a standpipe or branch is connected by screwing the thickness is to be measured at the root of the thread.

For boiler, superheater or economiser tubes the minimum thickness of the drum or header connection or tube stub is to be calculated as part of the tube in accordance with 222.

HEADERS

Rectangular Section Headers

219 The thickness of flat surfaces of rectangular solid forged headers (exclusive of staggered, sinuous or corrugated headers) is not to be less than:—

$$T + 0{,}75 \text{ mm} \quad (T + 0{\cdot}03 \text{ in}) \qquad (1)$$

where T = the greatest basic thickness, in mm (in), derived as follows by the use of Chart J 2.6 which gives ratios of thickness to effective width of header.

Two investigations are necessary to deal with:—

(i) the stress at the corner of the header,

(ii) the stress in the ligaments between tube holes or other openings piercing the flat face of the header.

The efficiency J of the ligaments is calculated as in 202 to 205.

Where a header is drilled for several rows of tube holes the lowest calculated efficiency is to be used.

Chart J 2.6 shows values of $\frac{T}{B}$ corresponding to values of a term K for parameters of $\frac{A}{B}$

where A = the distance, in mm (in), between the centre line of the openings and the limit of the effective width "B" of the header (where there is more than one row of holes, "A" is the distance to the row showing the lowest efficiency),

B = the effective width, in mm (in), of the pierced surface under consideration measured between the supporting sides of the headers, minus one corner radius. This effective width is not to be taken as less than 0,9 of the full distance between the sides.

The corner radius is not to be less than 6,5 mm (0·25 in) (*see* illustration of "A" and "B" on Chart J 2.6).

$$K = \frac{f\,J}{P}$$

where P and f are as defined in J 110,

J = the lowest ligament efficiency expressed as a fraction.

It will be seen that in case (i) $\frac{A}{B} = 0$ and $J = 1$.

Where the header surfaces are machined locally at hand holes the total thickness may be reduced by a maximum of 4 mm (0·15 in).

Except for small areas not exceeding 3,25 cm² (0·5 in²) where a reduction of designed thickness up to 50 per cent may be permitted, the thickness derived from use of Chart J 2.6 is to be the minimum. Such minimum is in no case to be less than 7,5 mm (0·3 in) or, where tube holes are drilled, to be less than

$$T = 0{,}5\sqrt{d} + 6{,}35 \text{ mm} \qquad (2)$$

$$(T = 0{\cdot}1\sqrt{d} + 0{\cdot}25 \text{ in})$$

where d = the diameter of the tube hole, in mm (in).

Staggered, Sinuous or Corrugated Headers

220 The scantlings of staggered, sinuous or corrugated headers shall be the subject of special consideration.

Where sufficient experience of previous satisfactory service of similar headers cannot be shown, the suitability of headers is to be proved in accordance with the provisions of J 108.

Header Ends

221 The shape and thickness of ends forged integrally with the bodies of headers are to be the subject of special consideration.

Where sufficient experience of previous satisfactory service of headers with similar ends cannot be shown the suitability of a proposed form of end is to be proved in accordance with the provisions of J 108.

Ends attached by welding are to be designed as follows:—

(*a*) *Dished ends.* These are to be in accordance with 209.

(*b*) *Flat ends.* The minimum thickness of flat end plates is to be determined by the following formula:—

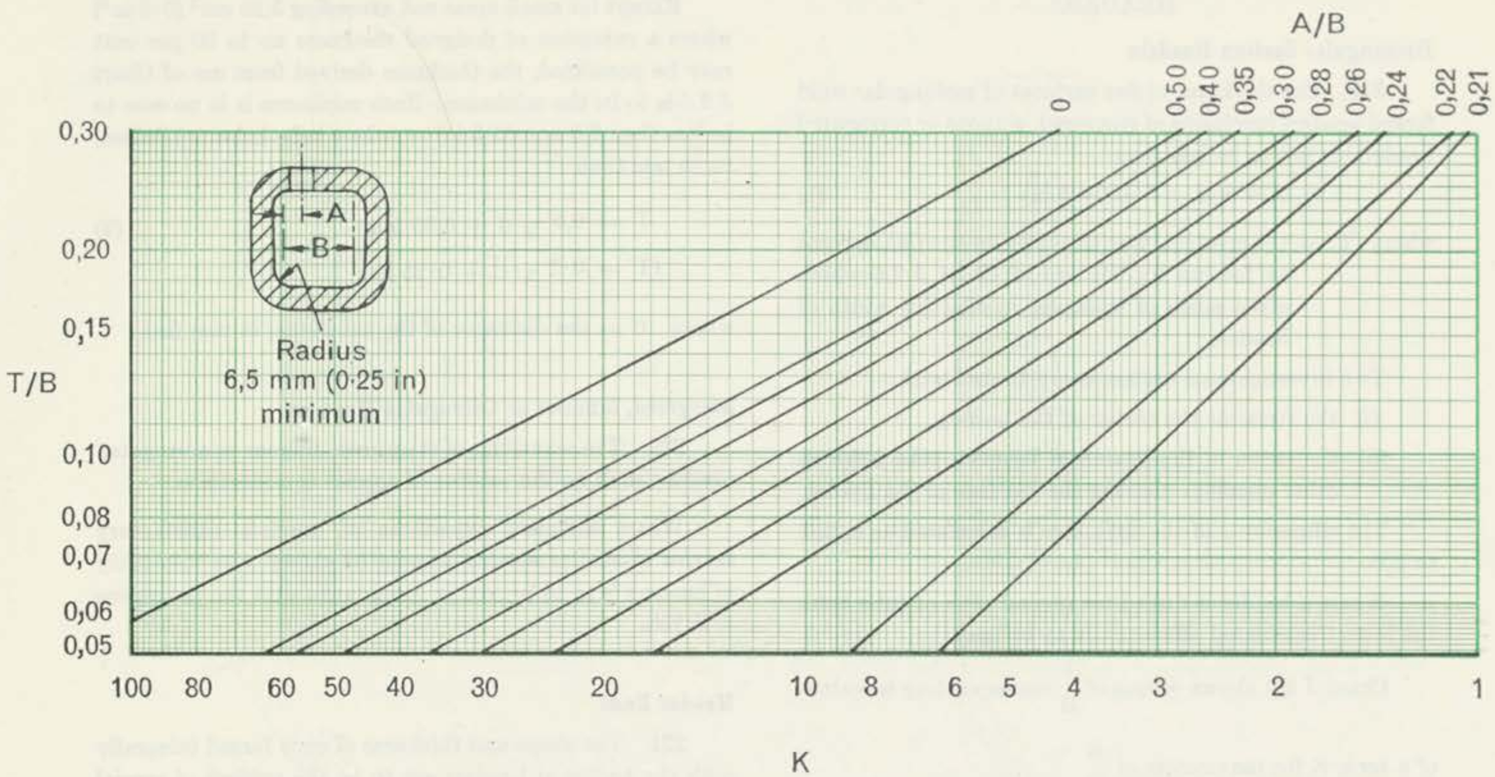
$$T = d_i\sqrt{\frac{P\,C}{f}}$$

where P and f are as defined in J 110,

T = minimum thickness of end plate, in mm (in),

d_i = internal diameter of circular header or least width between walls of rectangular header, in mm (in),

C = a constant depending on method of end attachment (*see* Fig. J 2.13).



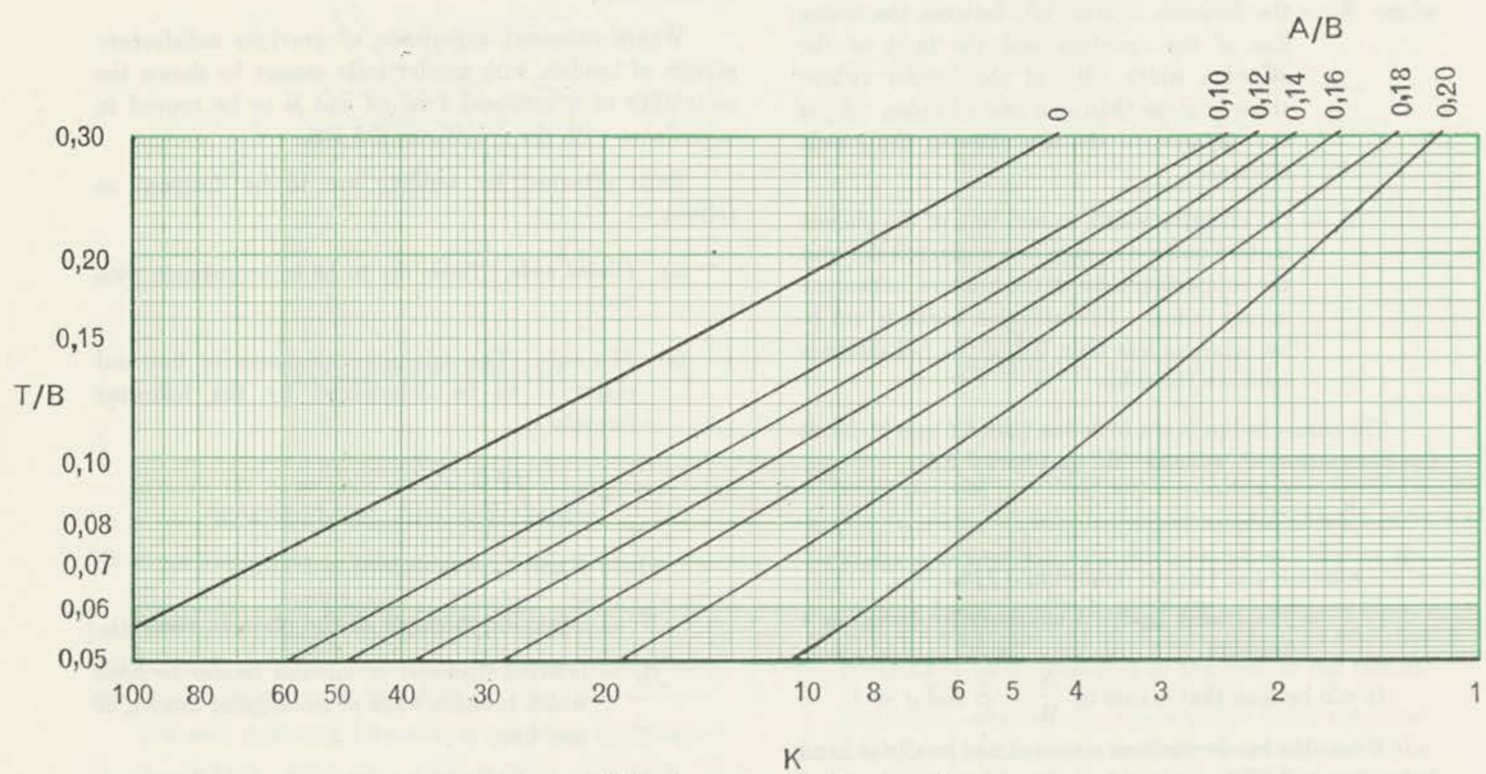


Chart J 2.6 Rectangular Section Headers

For end plates welded as shown in Fig. J 2.13a

C = 0,19 for circular headers,
0,32 for rectangular headers.

For end plates welded as shown in Figs. J 2.13b and J 2.13c.

C = 0,28 for circular headers,
0,40 for rectangular headers.

Where flat end plates are bolted to flanges attached to the ends of headers the flanges and end plates are to be in accordance with recognised pipe flange standards.

BOILER TUBES SUBJECT TO INTERNAL PRESSURE

Minimum Thickness

222 The minimum wall thickness T of tubes subject to internal pressure is to be determined by the following formula:—

$$T = \frac{P D_o}{2f + P}$$

where T, P, D_o and f are as defined in J 110.

The thickness T is in no case to be less than the minimum shown in Table J 2.2.

It should be noted that T derived from the above formula is the minimum thickness of straight tubes and further provision must be made for minus tolerances where necessary and also in cases where abnormal corrosion or erosion is expected in service. For bending allowances, *see* 224.

It is recommended that the thickness of tubes determined by the above formula be increased by 0,25 mm (0·01 in) for tubes subject to internal pressure and fitted in cylindrical boilers, and also tubes of low pressure water tube boilers having a design pressure of 17,5 kg/cm² (250 lb/in²) and under with open feed systems.

The minimum thickness of boiler, superheater, reheater and economiser tubes is to be determined by using the design stress appropriate to the mean wall temperature which shall be considered to be the metal temperature. Unless it is otherwise agreed between the manufacturer and

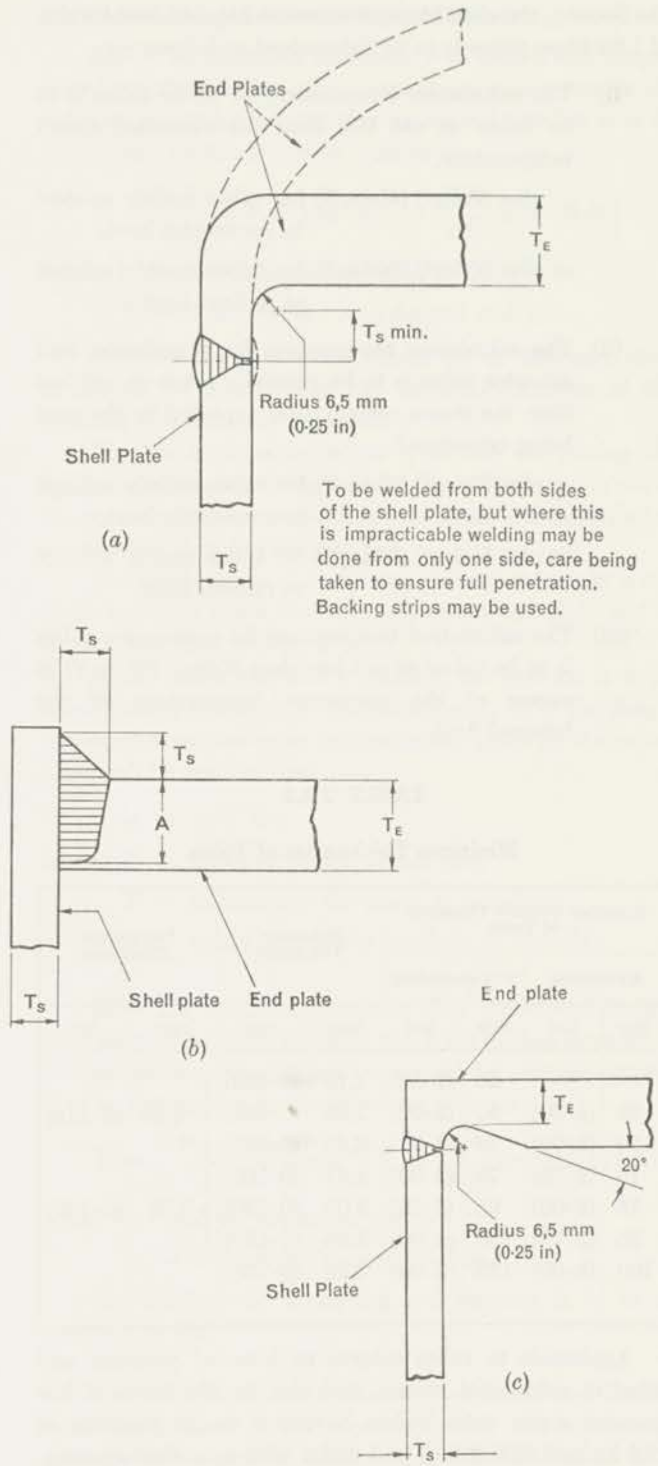


FIG. J 2.13 TYPICAL METHODS OF ATTACHMENT OF HEADER END CLOSURES

T_S = thickness of unpierced shell.
T_E = thickness of end plate.
A = $2T_S$ or T_E − 1,6 mm (T_E − 0·0625 in) whichever is less.

the Society, the metal temperature used to decide the value of f for these tubes is to be determined as follows:—

(i) The calculation temperature for boiler tubes is to be taken as not less than the saturated steam temperature,

plus 25degC (45degF) for tubes mainly subject to convection heat,

or plus 50degC (90degF) for tubes mainly subject to radiant heat.

(ii) The calculation temperature for superheater and reheater tubes is to be generally taken as not less than the steam temperature expected in the part being considered,

plus 35degC (63degF) for tubes mainly subject to convection heat,

or plus 50degC (90degF) for tubes mainly subject to radiant heat.

(iii) The calculation temperature for economiser tubes is to be taken as not less than 35degC (63degF) in excess of the maximum temperature of the internal fluid.

TABLE J 2.2

Minimum Thicknesses of Tubes

Nominal Outside Diameter of Tube				Minimum Thickness		*Minimum Thickness	
Exceeding		Not exceeding					
mm	(in)	mm	(in)	mm	(in)	mm	(in)
—	—	38	(1·50)	1,75	(0·069)	2,95	(0·116)
38	(1·50)	50	(2·00)	2,16	(0·085)		
50	(2·00)	70	(2·75)	2,40	(0·095)		
70	(2·75)	75	(3·00)	2,67	(0·105)	3,28	(0·129)
75	(3·00)	95	(3·75)	3,05	(0·120)		
95	(3·75)	100	(4·00)	3,28	(0·129)		
100	(4·00)	125	(5·00)	3,50	(0·138)		

* Applicable to tubes subject to internal pressure and fitted in cylindrical boilers, and also for the tubes of low pressure water tube boilers having a design pressure of 17,5 kg/cm² (250 lb/in²) and under with open feed systems.

223 The minimum thickness of downcomer tubes and pipes which form an integral part of the boiler and which are not exposed to combustion gases is to comply with the Rules for steam pipes.

Tube Bending

224 Where boiler, superheater, reheater and economiser tubes are bent, the resulting thickness of the tubes at the thinnest part is not to be less than that required for straight tubes, unless it can be demonstrated that the method of forming the bend results in no decrease in strength at the bend as compared with the straight tube. The manufacturer is to demonstrate in connection with any new method of tube bending that this condition is satisfied.

Tube bending and subsequent heat treatment, where necessary, is to be so carried out as to ensure that residual stresses do not adversely affect the strength of the tube for the design purpose intended.

Cross-references

225 For details of manholes, sight holes and doors, *see* J 301 to J 307.

For details of tube holes and fitting of tubes, *see* J 313.

Tube Plates of Vertical Boilers

226 Where vertical boilers have a nest or nests of horizontal tubes so that there is direct tension on the tube plates due to the vertical load on the boiler ends or to their acting as horizontal ties across the shell, the thickness of the tube plates in way of the outer rows of tubes is to be determined by the following formula:—

$$T = \frac{2\,P\,D}{J\,R_{20}} + 0{,}75 \text{ mm} \quad \left(T = \frac{2\,P\,D}{J\,R_{20}} + 0{\cdot}03 \text{ in}\right)$$

where T and P are as defined in J 110,

D = twice the radial distance of the centre of the outer row of tube holes from the axis of the shell, in mm (in),

R_{20} = specified minimum tensile strength of tube plate, in kg/cm² (lb/in²),

J = efficiency of ligaments between tube holes in the outer vertical rows (expressed as a fraction),

i.e. $J = \dfrac{(p - d)}{p}$

where p = vertical pitch of tubes, in mm (in),

d = diameter of tube holes, in mm (in).

Each alternate tube in the outer vertical rows of tubes is to be a stay tube. Further, the arrangement of stay tubes in the nests is to be such that the thickness of the tube plates meet the requirements of 243 and 244.

Where the vertical height of the tube plates between the top and bottom shelves exceeds 0,65 times the internal diameter of the boiler, the staying of the tube plates, and the scantlings of the tube plates and shell plates to which the sides of the tube plates are connected, will require to be specially considered. It is recommended, however, that for this type of boiler, the vertical height of the tube plates between the top and bottom shelves should not exceed 1,25 times the internal diameter of the boiler.

Horizontal Shelves of Tube Plates Forming Part of the Shell

227 For vertical boilers of the type referred to in 226, in order to withstand the vertical load due to pressure on the boiler ends the horizontal shelves of the tube plates are to be supported by gussets in accordance with the following formula:—

$$C = \frac{A\,D_i\,P}{T}$$

where A = maximum horizontal dimension of the shelf from the inside of the shell plate to the outside of the tube plate, in mm (in),

D_i = inside diameter of the boiler, in mm (in),

P = design pressure, in kg/cm^2 (lb/in^2),

T = thickness of the tube plate, in mm (in).

For the combustion chamber tube plate the minimum number of gussets shall be:—

1 gusset where C exceeds 261 000 (146 000),

2 gussets where C exceeds 357 000 (200 000),

3 gussets where C exceeds 428 000 (240 000).

For the smoke box tube plate the minimum number of gussets shall be:—

1 gusset where C exceeds 261 000 (146 000),

2 gussets where C exceeds 482 000 (270 000).

The shell plates to which the sides of the tube plates are connected are not to be less than 1,6 mm (0·0625 in) thicker than is required by the formula applicable to shell plates with continuous circularity; and where gussets or other stays are not fitted to the shelves, the strength of the parts of the circumferential seams at the top and bottom of these plates from the outside of one tube plate to the outside of the other, is to be sufficient to withstand the whole load on the boiler end with a factor of safety of not less than 4,5 related to R_{20} (R_{20} being the specified minimum tensile strength of the shell plates, in kg/cm^2 (lb/in^2)).

Dished and Flanged Ends for Vertical Boilers

228 The minimum thickness T of dished and flanged ends for vertical boilers which are subject to pressure on the concave side and are supported by central uptakes is to be determined by the following formula:—

$$T = \frac{P\,R_i}{2\,f_2} + 0{,}75\text{ mm} \quad \left(T = \frac{P\,R_i}{2\,f_2} + 0{\cdot}03\text{ in}\right)$$

where T, P and R_i are as defined in J 110,

f_2 = 0,65f where f is as defined in J 110.

The inside radius of curvature R_i of the end plate is not to be greater than the external diameter of the cylinder to which it is attached.

The inside knuckle radius r_i of the arc joining the cylindrical flange to the spherical surface of the end is not to be less than four times the thickness of the end plate and in no case less than 65 mm (2·5 in).

The inside radius of curvature of flange to uptake is not to be less than twice the thickness of the end plate and in no case less than 25 mm (1 in).

If the dished end has a manhole the opening is to be strengthened by flanging. The total depth, H, of the flange, measured from the outer surface of the plate on the minor axis shall be not less than:—

$$H = \sqrt{T\,W}$$

where H = depth of flange, in mm (in),

T = thickness of the plate, in mm (in),

W = minor axis of the manhole, in mm (in).

229 The minimum thickness T of dished and flanged ends for vertical boiler furnaces which are subject to pressure on the convex side and are supported by central uptakes is to be determined by the following formula:—

$$T = \frac{P\,R_o}{2\,f_3} + 0{,}75\text{ mm} \quad \left(T = \frac{P\,R_o}{2\,f_3} + 0{\cdot}03\text{ in}\right)$$

where T, P and R_o are as defined in J 110,

f_3 = 0,5f where f is as defined in J 110.

The inside radii of dishing and flanging is to be as required by 228.

230 The minimum thickness T of dished and flanged ends for vertical boiler furnaces, which are subject to pressure on the convex side and are without support from stays of any kind, is to be determined by the following formula but is in no case to be less than the thickness of the firebox:—

$$T = \frac{C\,P\,R_o}{675} + 0{,}75\text{ mm} \qquad \left(T = \frac{C\,P\,R_o}{9600} + 0{\cdot}03\text{ in}\right)$$

where T and P are as defined in J 110,

R_o = outside radius of the crown plate, in mm (in).

In no case is $\frac{R_o}{T}$ to exceed 88.

$C = \frac{2x}{x + f}$ which must not be taken as less than 0,85 where x and f are as defined in 232.

The inside radius of curvature, R_i, of the end plate is not to be greater than the external diameter of the cylinder to which it is attached.

The inside knuckle radius r_i of the arc joining the cylindrical flange to the spherical surface of the end is not to be less than four times the thickness of the end plate and in no case less than 65 mm (2·5 in).

CYLINDRICAL FURNACES SUBJECT TO EXTERNAL PRESSURE

NOTE:—Furnaces, plain or corrugated, are not to exceed 22,5 mm (0,875 in) in thickness.

Corrugated Furnaces

231 The minimum thickness T of corrugated furnaces is to be determined by the following formula:—

$$T = \frac{P D_o}{C} + 0{,}75 \text{ mm} \qquad \left(T = \frac{P D_o}{C} + 0\cdot 03 \text{ in}\right)$$

where P is as defined in J 110,

D_o = external diameter of the furnace measured at the bottom of the corrugations, in mm (in),

T = thickness of the furnace plate measured at the bottom of the corrugations, in mm (in),

C = 1080 (15 350) for Fox, Morison and Deighton corrugations,

= 1150 (16 300) for Suspension Bulb corrugations.

Plain Furnaces, Flue Sections and Combustion Chamber Bottoms

232 The minimum thickness T of plain furnaces or furnaces strengthened by the Adamson or other joints, of flue sections and of the cylindrical bottoms of combustion chambers is to be determined by the following formulæ, the greater of the two thicknesses obtained being taken:—

$$T = \sqrt{\frac{P D_o (L + 610)}{104\,400}} + 0{,}75 \text{ mm} \qquad (1)$$

$$\left(T = \sqrt{\frac{P D_o (L + 24)}{1\cdot 5 \times 10^6}} + 0\cdot 03 \text{ in}\right)$$

$$T = \frac{C P D_o}{1120} + \frac{L}{320} + 0{,}75 \text{ mm} \qquad (2)$$

$$\left(T = \frac{C P D_o}{16\,000} + \frac{L}{320} + 0\cdot 03 \text{ in}\right)$$

where T and P are as defined in J 110,

D_o = external diameter of the furnace, flue or combustion chamber, in mm (in),

L = length of section between the centres of points of substantial support, in mm (in),

$C = \frac{2x}{x + f}$

x = 0,2% proof stress, in kg/cm² (lb/in²), at a temperature 90degC (162degF) above the saturated steam temperature corresponding to the design pressure for 42–52 kg/mm² (26·7–33·0 ton/in²) carbon steel Category II material as shown in Chapter Q, Table Q 3.4.

f = minimum specified 0,2% proof stress, in kg/cm² (lb/in²) at temperature 90degC (162 degF) above the saturated steam temperature corresponding to the design pressure for the steel actually used.

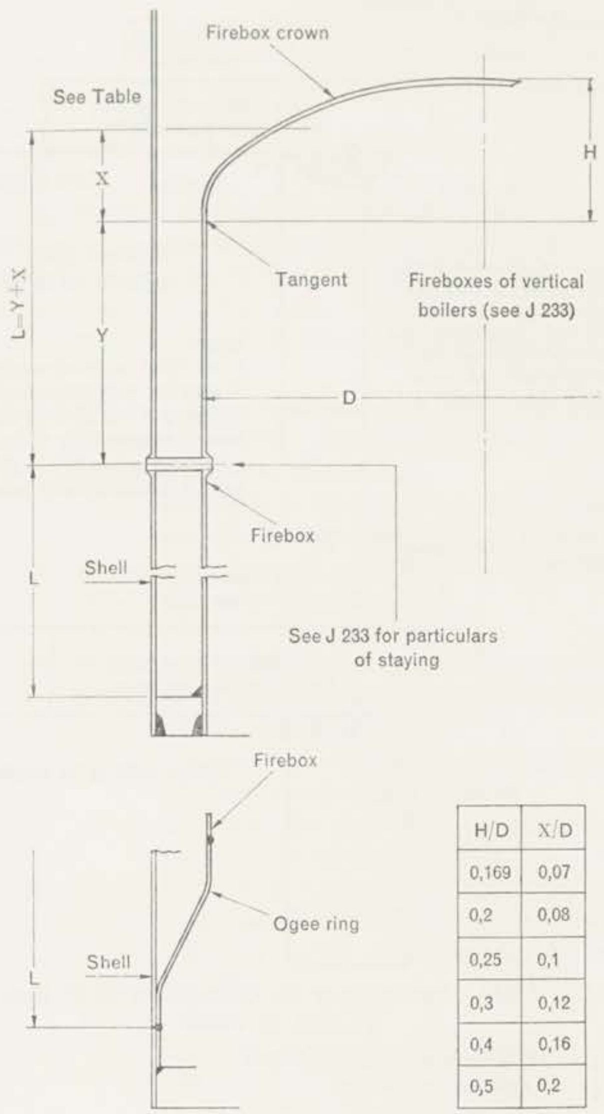
Plain Furnaces of Vertical Boilers

233 The thickness of plain furnaces not exceeding 1700 mm (5 ft 6 in) in external diameter is to be determined by the formulæ given in 232; the greater of the two thicknesses being taken:—

where D = external diameter of the furnace, in mm (in). Where the furnace is tapered, the diameter to be taken for calculation purposes is to be the mean of that at the top and that at the bottom where it meets the substantial support from flange, ring or row of stays,

L = effective length, in mm (in), of the furnace between the points of substantial support as indicated in Fig. J 2.14.

In no case, however, is the thickness to be more than 22,5 mm (0·875 in). For furnaces under 760 mm (2 ft 6 in) in external diameter the thickness is not to be less than 8 mm (0·3125 in), and for furnaces 760 mm (2 ft 6 in) in external diameter and over, the thickness is not to be less than 9,5 mm (0·375 in). Furnaces exceeding 1700 mm (5 ft 6 in) in external diameter shall be the subject of special consideration.



H/D	X/D
0,169	0,07
0,2	0,08
0,25	0,1
0,3	0,12
0,4	0,16
0,5	0,2

Fig. J 2.14 Effective Length "L" for use in J 233

A circumferential row of stays connecting the furnace to the shell shall be considered to provide substantial support to the furnace, provided:—

(*a*) the diameter of the stay be not less than 22,5 mm (0·875 in) or twice the thickness of the furnace, whichever is the greater. In the case of screwed stays the diameter is to be measured over the threads.

(*b*) the pitch of the stays at the furnace does not exceed 14 times the thickness of the furnace.

Hemispherical Furnaces

234 The minimum thickness T of unsupported hemispherical furnaces subject to pressure on the convex surface is to be determined by the following formula:—

$$T = \frac{C\,P\,R_o}{620} + 0{,}75\ \text{mm} \qquad \left(T = \frac{C\,P\,R_o}{8800} + 0{\cdot}03\ \text{in}\right)$$

where T and P are as defined in J 110,

R_o = outer radius of curvature of the furnace, in mm (in),

$C = \dfrac{2x}{x + f}$ which must not be taken as less than 0,85.

x and f are as defined in 232.

In no case, however, is T to exceed 22,5 mm (0·875 in) and the ratio $\left(\dfrac{R_o}{T} - 0{,}03\right)$ to exceed 100.

Ogee Rings

235 The minimum thickness T of the ogee ring which connects the bottom of the furnace to the shell of a vertical boiler and sustains the whole vertical load on the furnace is to be determined by the following formula:—

$$T = \sqrt{\frac{P\,D_i\,(D_i - D_o)}{10\,110}} + 0{,}75\ \text{mm}$$

$$\left(T = \sqrt{\frac{P\,D_i\,(D_i - D_o)}{144\,000}} + 0{\cdot}03\ \text{in}\right)$$

where T and P are as defined in J 110,

D_i = inside diameter of boiler shell, in mm (in),

D_o = outside diameter of the lower part of the furnace where it joins the ogee ring, in mm (in).

Uptakes of Vertical Boilers

236 The minimum thickness T of internal uptakes of vertical boilers is to be determined by the following formulæ, the greater of the two thicknesses obtained being taken:—

$$T = \sqrt{\frac{P\,D_o\,(L + 610)}{104\,400}} + 4\ \text{mm} \qquad (1)$$

$$\left(T = \sqrt{\frac{P\,D_o\,(L + 24)}{1{\cdot}5 \times 10^6}} + 0{\cdot}156\ \text{in}\right)$$

$$T = \frac{P D_o}{1120} + \frac{L}{320} + 4 \text{ mm} \quad (2)$$

$$\left(T = \frac{P D_o}{16\,000} + \frac{L}{320} + 0{\cdot}156 \text{ in}\right)$$

where T and P are as defined in J 110,

D_o = external diameter of uptake, in mm (in),

L = length of uptake between the centres of points of substantial support, in mm (in).

Cross Tubes

237 Cross tubes shall not exceed 300 mm (12 in) internal diameter. The minimum thickness T is to be determined by the following formula but is in no case to be less than 9,5 mm (0·375 in).

$$T = \frac{P D_i}{450} + 6{,}5 \text{ mm} \quad \left(T = \frac{P D_i}{6400} + 0{\cdot}25 \text{ in}\right)$$

where T and P are as defined in J 110,

D_i = internal diameter of cross tube, in mm (in).

Stayed Flat Surfaces

238 Where flat end plates are flanged for connection to the shell, the inside radius of flanging is not to be less than 1,75 times the thickness of the plate, with a minimum of 38 mm (1·5 in).

Where combustion chamber or firebox plates are flanged for connection to the wrapper plate, the inside radius of flanging is to be equal to the thickness of the plate, with a minimum of 25 mm (1 in).

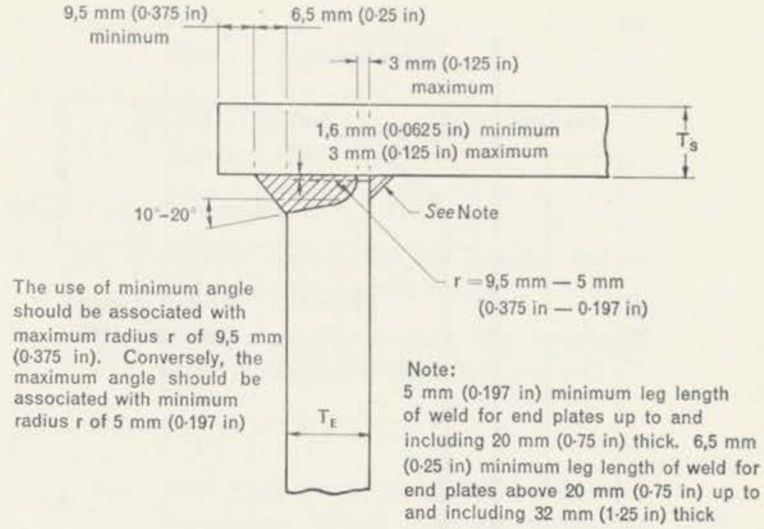
Where unflanged flat plates are connected to the shell by welding, the methods of attachment are to be as shown in Fig. J 2.15. Similar forms of attachment may be used where unflanged combustion chamber or fire box plates are connected to the wrapper plate by welding.

239 Where the flange curvature is a point of support, this is to be taken at the commencement of curvature, or at a line 3,5 times the thickness of the plate measured from the outside of the plate, whichever is nearer to the flange.

Where a flat plate is welded directly to a shell or wrapper plate, the point of support is to be taken at the inside of the shell or wrapper plate.

240 The thickness T of those portions of flat plates supported by stays is to be determined by the following formula:—

$$T = Cd\sqrt{\frac{P}{f_1}} + 0{,}75 \text{ mm} \quad \left(T = Cd\sqrt{\frac{P}{f_1}} + 0{\cdot}03 \text{ in}\right)$$



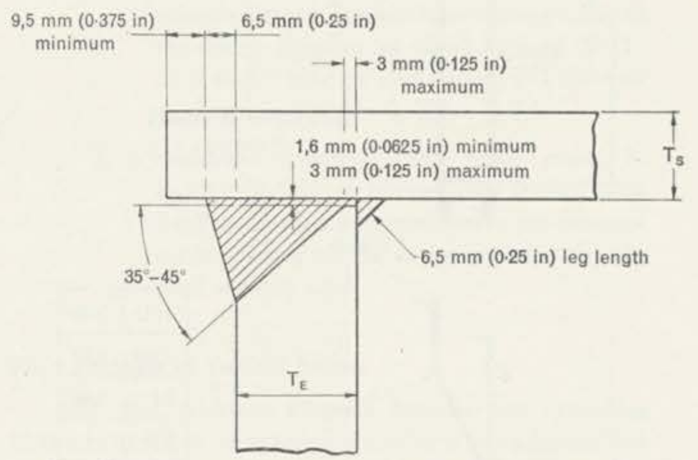


FIG. J 2.15 ATTACHMENT OF UNFLANGED FLAT END PLATES TO SHELL

T_S = thickness of cylindrical shell
T_E = thickness of flat end

where T and P are as defined in J 110,

f_1 = 0,85 f where f is as defined in J 110,

$d = \sqrt{A^2 + B^2}$ where the stays are regularly pitched.

A being the horizontal pitch of the stays and

B the vertical pitch of the stays.

Where the stays are irregularly pitched, then

d = diameter of the largest circle which can be drawn through three points of support without enclosing another point of support. Only two points of support may lie on one side of any diameter of the circle.

Where a flange is taken as a point of support, the circumference of the circle is to be tangent to the line of curvature (*see* 239).

C = a constant, depending on the method of support as detailed below. Where various forms of support are used the constant C is to be the mean of the values for the respective methods adopted.

Alternative methods of support will be specially considered.

All constants given in this paragraph relate to plates which are stress relieved and not exposed to flame. Where the plates are exposed to flame the thickness of the plate is to be increased by 10 per cent.

The value of C in the above formula is to be as follows:—

(1) Where stays are screwed through the plates and, in addition, are fillet welded to the plates on the outside as shown in Fig. J 2.16:—

C = 0,39 where the fillet weld is 0,35 times the stay diameter over the thread.

(2) Where plain stays are strength welded into the plates as shown in Fig. J 2.17:—

C = 0,39.

(3) Where plain bar stays pass through holes in the plates and are fitted on the outside with washers as shown in Fig. J 2.18:—

C = 0,35 where the diameter of the washer is 3,5 times the diameter of the stay.

C = 0,33 where the diameter of the washer is 0,67 times the pitch of the stays.

(4) Where the flat plate is flanged for attachment to the shell, flue, furnace or wrapper or alternatively is welded directly to the shell, flue, furnace or wrapper (*see* 239):—

C = 0,33.

(5) Where the support is a gusset or link stay:—

C = 0,39.

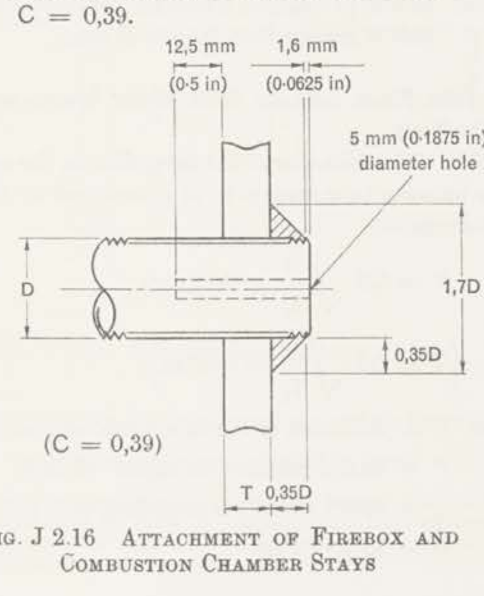


FIG. J 2.16 ATTACHMENT OF FIREBOX AND COMBUSTION CHAMBER STAYS

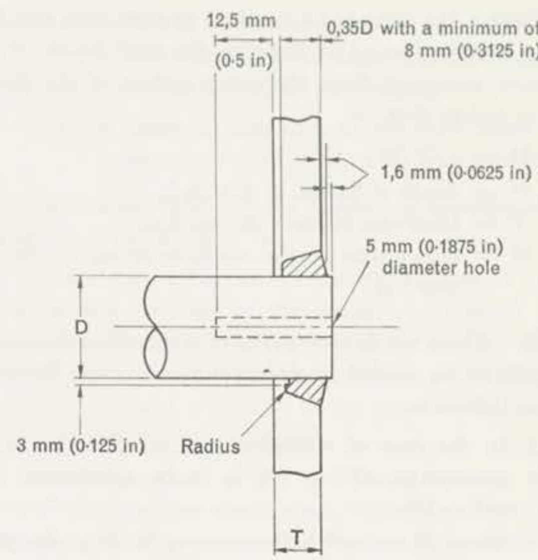


FIG. J 2.17 ATTACHMENT OF FIREBOX, COMBUSTION CHAMBER STAYS AND BAR STAYS

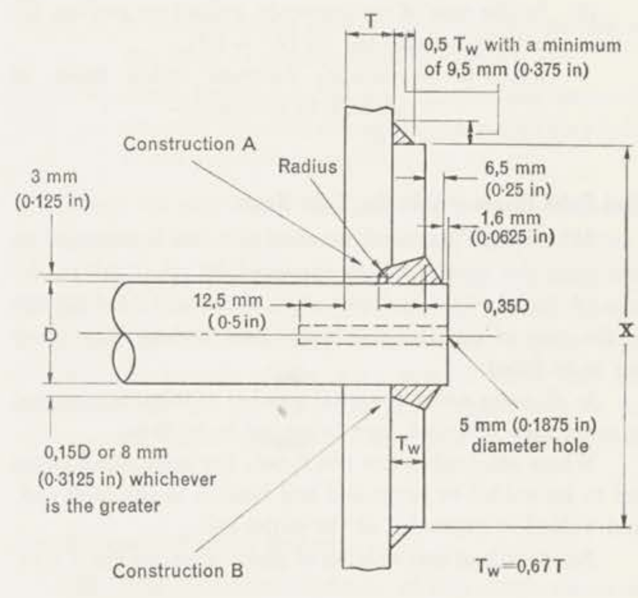


FIG. J 2.18 ATTACHMENT OF BAR STAYS

Method of construction "A" or "B" may be used except where T_W is less than 0,35D when the form of construction shown in "A" is to be used.

Diameter of washer "X"	Value of constant C
X = 3,5D	0,35
X = 0,67 pitch of stays	0,33

Where a flat plate has a manhole or sight hole and the opening is strengthened by flanging, the total depth, H, of the flange, measured from the outer surface of the plate, is not to be less than:—

$$H = \sqrt{T\,W}$$

where H = depth of flange, in mm (in),
T = thickness of plate, in mm (in),
W = minor axis of the manhole or sight hole, in mm (in).

241 Where the flat top plates of combustion chambers are supported by welded-on girders the equation in 240 is to apply as follows:—

(1) In the case of welded-on girders provided with waterways, $(X^2 + Y^2)$ is to be substituted for $(A^2 + B^2)$.
where X = width of waterway in the girder plus the thickness of the girder, in mm (in),
Y = pitch of girders, in mm (in):—
C = 0,42.

(2) In the case of continuously welded-on girders, D^2 is to be substituted for $(A^2 + B^2)$,
where D = distance between inside faces of girders, in mm (in):—
C = 0,51.

Flat Tube Plates within the Tube Nests

242 Where the total number of tubes is arranged in one nest, the area of which exceeds 0,65 m^2 (7 ft^2) in the case of directly fired multitubular boilers, and 2 m^2 (21 ft^2) in the case of multitubular waste heat boilers, stay tubes are to be fitted.

In all cases where the total number of tubes is arranged in more than one nest, stay tubes are to be fitted.

Where stay tubes are not fitted, the ends of all tubes are to be welded or expanded and beaded at the inlet end, and welded or expanded at the outlet end.

For details of seal welding of plain tubes, *see* Fig. J 2.19.

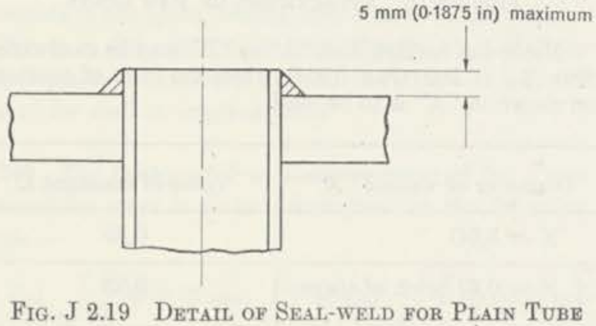


FIG. J 2.19 DETAIL OF SEAL-WELD FOR PLAIN TUBE

243 Where stay tubes are required to be fitted the thickness of those parts of the tube plates within the tube nests is to be determined by the following formula:—

$$T = CM\sqrt{\frac{P}{f_5}} + 0{,}75 \text{ mm}$$

$$\left(T = CM\sqrt{\frac{P}{f_5}} + 0\cdot03 \text{ in}\right)$$

where T = thickness of tube plate, in mm (in),
P = design pressure, in kg/cm^2 (lb/in^2),
f_5 = 0,85 f where f is as defined in J 110,
M = mean pitch, in mm (in), of the stay tubes supporting any positions of the plate (being the sum of the four sides of any quadrilateral divided by 4),
C = 0,42 for plates not exposed to flame with stay tubes secured as shown in Fig. J 2.20,
C = 0,46 for plates exposed to flame.

Where the area of the tube nest does not exceed 0,65 m^2 (7 ft^2) in the case of direct fired boilers or 2 m^2 (21 ft^2) in the case of waste heat boilers, and stay tubes are not fitted, the thickness of the tube plates is to be determined by the above formula:—

where M = four times the mean pitch, in mm (in), of the plain tubes in the nest,
C = 0,45 for plates not exposed to flame,
C = 0,49 for plates exposed to flame.

The thickness T of any tube plate in the tube area is not to be less than:—

(*a*) 12,5 mm (0·5 in) where the diameter of the tube hole does not exceed 50 mm (2 in) and

(*b*) 14 mm (0·5625 in) where the diameter of the tube hole is greater than 50 mm (2 in).

Flat Tube Plates between Wide Water Spaces and around Tube Nests

244 The thickness of the tube plate in the wide water space between tube nests is to be determined by the following formula:—

$$T = Cd\sqrt{\frac{P}{f_5}} + 0{,}75 \text{ mm}$$

$$\left(T = Cd\sqrt{\frac{P}{f_5}} + 0\cdot03 \text{ in}\right)$$

where T = thickness of the tube plate, in mm (in),
P = design pressure, in kg/cm^2 (lb/in^2),
f_5 = 0,85 f where f is as defined in J 110,
$d = \sqrt{A^2 + B^2}$

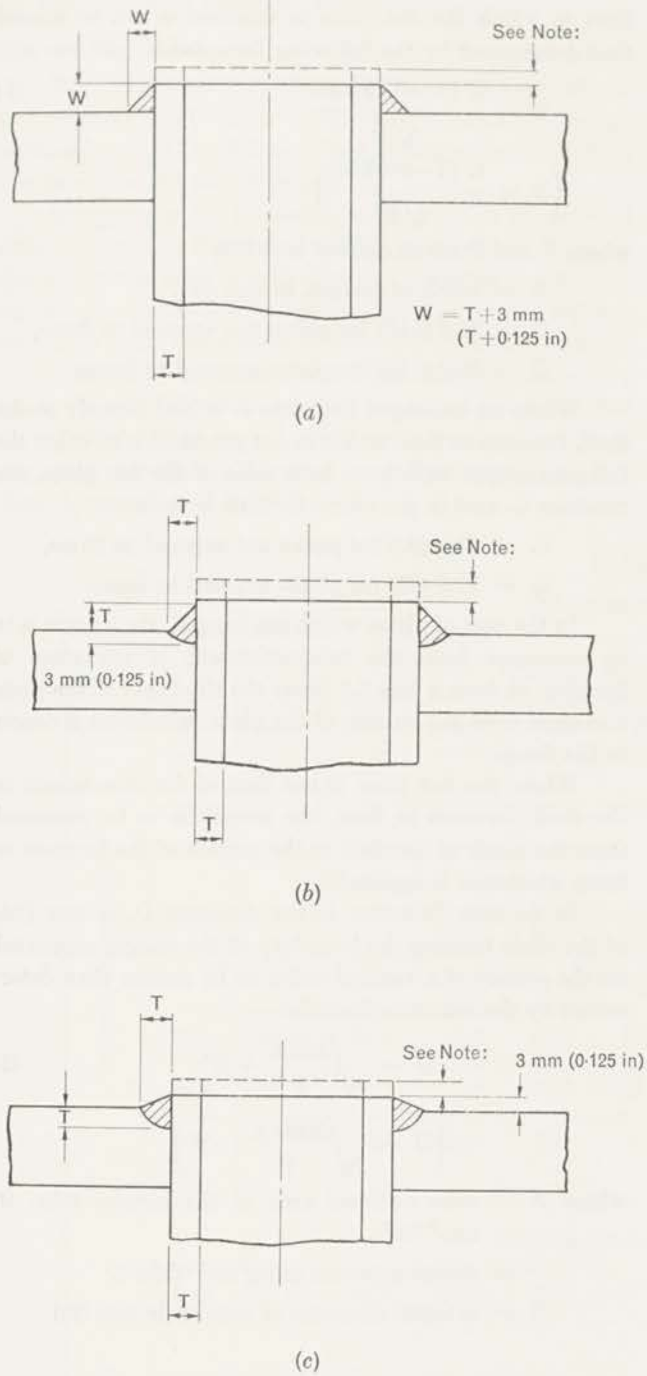


FIG. J 2.20 ATTACHMENT OF STAY TUBES

C = 0,42 if the plates are not exposed to flame

C = 0,46 if the plates are exposed to flame

NOTE.—The ends of the tubes are to be dressed flush with the welds when exposed to flame or comparatively high temperature. When not exposed, the ends of the tubes may extend a maximum of 9,5 mm (0·375 in) beyond the weld.

where A = width, in mm (in), of the wide water space between the tube nests (measured from the centre line of the stay tubes),

B = pitch, in mm (in), of the stay tubes in the boundary rows of the wide water space.

The values of C and the method of securing the stay tubes are as indicated in 243.

Where stay tubes are irregularly pitched d is to be taken as the diameter of the largest circle which can be drawn through any three points of support without enclosing another point of support. Where various forms of support are used, the value of C is to be the mean of the values for the respective methods adopted.

For the portions of the end plates between the top rows of tubes and the steam space stays, the above formula is to apply, B being taken as the distance between the centre line of the top row of tubes and the centre of the bar stays or other point of support, and A being taken as:—

$$\frac{A_1 + A_2}{2}$$

where A_1 is the horizontal distance between the centres of bar stays or other method of support, and

A_2 is the horizontal distance between the centre of one stay tube and the centre of the next stay tube in the top boundary row.

Where no stay tubes are fitted A_2 is to be taken as equal to four times the horizontal pitch of the plain tubes.

Where no stay tubes are fitted the support afforded by the plain tubes is not to be taken to extend beyond the line enclosing the outer surfaces of the tubes except that, between the outside of the wing row of tubes and the attachment of the end plate to shell, there may be an unsupported width equal to the flat plate margin as given by 248, formula (1).

Flat Crowns of Vertical Boilers

245 The minimum thickness of flat crown plates of vertical boilers is to be determined by 240; d and C being defined as follows:—

(*a*) Where the crown is supported by an uptake only,

d = diameter, in mm (in), of the largest circle which can be drawn between the connections to the shell or firebox and uptake (*see* 238 and 239),

C = 0,47 if the plates are not exposed to flame,

C = 0,51 if the plates are exposed to flame.

(*b*) Where bar stays are fitted in accordance with 240,

d = diameter, in mm (in), of the largest circle which can be drawn through three points of support without enclosing another point of support,

C = the mean of the values for the respective points of support through which the circle passes.

Combustion Chamber Tube Plates under Compression

246 The thickness of combustion chamber tube plates under compression, due to the pressure on the top plate, based on a compressive stress not exceeding 980 kg/cm² (14 000 lb/in²) is to be determined by the following formula:—

$$T = \frac{P\,W\,p}{1970\,(p-d)} \qquad \left(T = \frac{P\,W\,p}{28000\,(p-d)}\right)$$

where T and P are as defined in J 110,

W = width of the combustion chamber, in mm (in), measured inside from tube plate to back chamber plate,

p = pitch of tubes, in mm (in), measured horizontally where tubes are chain pitched, or diagonally where the tubes are staggered pitched and the diagonal pitch is less than the horizontal pitch,

d = internal diameter of the plain tubes, in mm (in).

Girders for Combustion Chamber Top Plates

247 The proportions of steel plate girders supporting the tops of combustion chambers is to be determined by the following formula:—

$$T = \frac{3{,}2\,P\,l^2\,p}{d^2\,R_{20}}$$

where T and P are as defined in J 110,

d = depth of girder, in mm (in),

l = length of girder, in mm (in), measured inside from tube plate to back chamber plate,

p = distance apart of the girders, in mm (in),

R_{20} = specified minimum tensile strength of the girder plate, in kg/cm² (lb/in²).

The above formula is applicable to plate girders welded continuously to the top combustion chamber plate by means of a full penetration weld.

Flat Plate Margins

248 The width of margin, b, of a flat plate which may be regarded as being supported by the shell, furnaces or flues to which the flat plate is attached is not to exceed that determined by the following formula:—

$$b = \frac{C\,(T - 0{,}75\text{ mm})}{\sqrt{P}} \qquad (1)$$

$$\left(b = \frac{C\,(T - 0{\cdot}03\text{ in})}{\sqrt{P}}\right)$$

where T and P are as defined in J 110,

b = width of margin, in mm (in),

C = 31,3 (118) for plates not exposed to flame,

C = 29,2 (110) for plates exposed to flame.

Where an unflanged flat plate is welded directly to the shell, furnaces or flues and it is not practicable to effect the full penetration weld from both sides of the flat plate, the constant C used in the above formula is to be:—

C = 23,9 (90) for plates not exposed to flame,

C = 22,5 (85) for plates exposed to flame.

In the case of plates which are flanged, the margin is to be measured from the commencement of curvature of flanging, or from a line 3,5 times the thickness of the plate measured from the outside of the plate, whichever is nearer to the flange.

Where the flat plate is not flanged for attachment to the shell, furnaces or flues, the margin is to be measured from the inside of the shell or the outside of the furnaces or flues, whichever is applicable.

In no case, however, is the diameter D, in mm (in), of the circle forming the boundary of the margin supported by the uptake of a vertical boiler to be greater than determined by the following formula:—

$$D = \sqrt{\frac{352\,A}{P} + d^2} \qquad (2)$$

$$\left(D = \sqrt{\frac{5000\,A}{P} + d^2}\right)$$

where A = cross-sectional area of the uptake tube, in mm² (in²),

P = design pressure, in kg/cm² (lb/in²),

d = external diameter of uptake, in mm (in).

BOILER TUBES SUBJECT TO EXTERNAL PRESSURE INCLUDING PLAIN AND STAY SMOKE TUBES FOR CYLINDRICAL BOILERS

Stay Tubes

249 Each stay tube is to be designed to carry its due proportion of the load on the plates which it supports. No stay tube is to be less than 5 mm (0·1875 in) thick at its thinnest part.

Stay tubes may be attached to the tube plates either by screwing or by metal arc welding.

Screwed Stay Tubes

250 The maximum stress in a screwed stay tube is not to exceed 527 kg/cm² (7500 lb/in²) based on the net sectional area at the bottom of the thread or in the body of the stay tube, whichever is less.

If stay tubes are increased in thickness at the screwed ends so that the thickness at the bottom of the thread is practically the same as in the body of the tube, the thickening is to be attained by upsetting and not by any welding process, and the tubes are to be annealed after the upsetting.

Where stay tubes are screwed into the tube plates they are to be screwed with a continuous thread not finer than 11 threads per 25,4 mm (1 in) at both ends and are to be expanded into the tube plates by roller expander and, if desired, may be seal welded.

Nuts are not to be fitted to stay tubes at the combustion chamber end.

Welded-in Stay Tubes

251 The thickness of stay tubes welded to tube plates is to be such that the maximum stress on the thinnest part of the tube does not exceed 705 kg/cm² (10 000 lb/in²).

Stay tubes are to be expanded into the tube plate in addition to welding. Typical examples of welded stay tube attachments are shown in Fig. J 2.20.

Stay tubes may be welded into the boiler after stress relief, provided they are not adjacent in the same tube nest.

Plain Tubes

252 The thickness of plain tubes is to be in accordance with Table J 2.3 for the appropriate outside diameter and design pressure.

TABLE J 2.3

Thickness of Plain Tubes

	Outside diameter in mm											Thickness
	38	**44,5**	**51**	**57**	**63,5**	**70**	**76**	**82,5**	**89**	**95**	**102**	mm
Design pressure kg/cm²										27,4	25,7	5,89
								26,7	24,6	23,2	21,8	5,38
							24,6	22,5	21,1	19,7	18,3	4,88
				28,1	25,3	23,2	21,1	19,7	18,3	16,9	16,2	4,47
		29,9	26,0	23,2	21,1	19,3	17,6	16,2	15,1	14,0	13,0	4,06
	27,1	23,2	21,1	18,3	16,2	15,1	13,4	12,6	11,6	10,5	9,8	3,66
	20,7	17,2	15,1	13,4	12,3	11,2	9,8	9,1	8,4	7,7	7,0	3,25
	15,1	12,6	10,9	9,8	8,8	7,7						2,95

	Outside diameter in inches											Thickness
	1·5	**1·75**	**2·0**	**2·25**	**2·5**	**2·75**	**3·0**	**3·25**	**3·5**	**3·75**	**4·0**	Inches
Design pressure lb/in²										390	365	0·232
								380	350	330	310	0·212
							350	320	300	280	260	0·192
				400	360	330	300	280	260	240	230	0·176
		425	370	330	300	275	250	230	215	200	185	0·160
	385	330	300	260	230	215	190	180	165	150	140	0·144
	290	245	215	190	175	160	140	130	120	110	100	0·128
	210	180	155	140	125	110						0·116

Plain tubes may be seal welded at both ends, seal welded at the inlet end and expanded at the outlet end, or expanded at both ends.

Where plain tubes are seal welded, the weld detail is to be as shown in Fig. J 2.19 and the tubes are to be expanded into the tube plates in addition to welding.

Where plain tubes are expanded only, the process is to be carried out with roller expanders, and the expanded portion of the tube is to be parallel through the full thickness of the tube plate. In addition to expanding, tubes may be bell-mouthed or beaded at the inlet end.

Where the total number of tubes is arranged in one nest and no stay tubes are fitted (*see* 242), the ends of all tubes are to be welded or expanded and beaded at the inlet end, and welded or expanded at the outlet end.

Pitch of Tubes

253 The spacing of tube holes is to be such that the minimum width, in mm (in), of any ligament between the tube holes is not less than:—

$$0{,}125\,d + 12{,}5 \text{ mm} \quad (0{\cdot}125\,d + 0{\cdot}5 \text{ in})$$

where d = diameter of the tube hole, in mm (in).

Combustion Chambers and Longitudinal Bar Stays

254 The permissible stress in combustion chamber and other similar bar stays, calculated on the minimum sectional area, is not to exceed 633 kg/cm² (9000 lb/in²). The diameter of any stay is not to be less than 19 mm (0·75 in).

255 The permissible stress in longitudinal stays, calculated on the minimum cross-sectional area, is not to exceed $\dfrac{\text{minimum specified tensile strength in kg/cm}^2\ (\text{lb/in}^2)}{5{,}3}$

In no case is the diameter of the stay at any section to be less than 25 mm (1 in).

Loads on Stay Tubes and Bar Stays

256 Stay tubes and bar stays are to be designed to carry the whole load due to the pressure on the area to be supported.

For a stay tube or bar stay, the net area to be supported is to be the area, in mm² (in²), enclosed by the lines bisecting at right angles the lines joining the stay and the adjacent points of support, less the area of any tubes or stays embraced. In the case of a stay tube or bar stay in the boundary rows the support afforded by the flat plate margin, where applicable, should be taken into account.

Where there are no stay tubes in the tube nest, the area to be supported by a bar stay is to extend to the tangential boundary of the tube nest.

Section 3

CONSTRUCTION

Access Arrangements

301 In watertube boilers, manholes are to be provided in all drums of sufficient size to permit access for internal examination and cleaning and for fitting and expanding the tubes. In the case of headers for water walls, superheaters or economisers and of drums which are too small to permit entry, sight holes or mudholes sufficiently large and numerous for these purposes are to be provided.

302 Cylindrical boilers are to be provided, where possible, with means for ingress to permit examination and cleaning of the inner surfaces of plates and tubes exposed to flame. Where the boilers are too small to permit this there are to be sight holes and mudholes sufficiently large and numerous to permit the inside to be satisfactorily cleaned.

303 Where the cross tubes of vertical boilers are large there is to be a sight hole in the shell opposite to one end of each tube sufficiently large to permit the tube to be examined and cleaned. These sight holes are to be in positions accessible for that purpose.

304 Unfired pressure vessels are to be so made that the internal surfaces may be examined and, wherever practicable, the openings for this purpose are to be sufficiently large for access and for cleaning the inner surfaces.

305 Manholes in cylindrical shells are to have their shorter axes arranged longitudinally, and are to be located clear of the welded joints in the shell.

306 Doors for manholes, mudholes and sight holes are to be formed from steel plate or of other approved construction and all jointing surfaces are to be machined.

The doors are to be of the internal type and are to be provided with spigots which have a clearance of not more than 1,5 mm (0·062 5 in) all round, i.e. the axes of the opening are not to exceed those of the door by more than 3 mm (0·125 in).

307 Doors for openings not larger than 230 mm × 180 mm (9 in × 7 in) need only be fitted with one stud which may be forged integral with the door. Larger doors are to be provided with two studs screwed through the door and fitted with nuts on the inside or alternatively, bolts may be used screwed through the door with the heads inside; other methods of attachment may be accepted provided details are submitted for consideration.

The crossbars or dogs are to be of steel.

For smaller circular openings in headers and similar fittings an approved type of plug may be used.

Torispherical and Semi-Ellipsoidal Ends

308 For typical acceptable methods of attaching dished ends to cylindrical shells and for limitations of different types, *see* Fig. J 3.1.

Types (d) and (e) are to be made a tight fit in the cylindrical shell.

Where the difference in thickness is the same throughout the circumference, the thicker plate is to be reduced in thickness by machining to a taper for a distance not less than four times the offset so that the two plates are of equal thickness at the position of the circumferential weld. A parallel portion may be provided between the end of the taper and the weld edge preparation; alternatively, if so desired, the width of the weld may be included as part of the smooth taper of the thicker plate (*see* J 510).

The thickness of the plates at the position of the circumferential weld is to be not less than that of an unpierced cylindrical shell of seamless or welded construction, whichever is applicable, of the same diameter and material (*see* J 209).

Hemispherical Ends

309 Where hemispherical ends are butt welded to cylindrical shells the thickness of the shell is to be reduced by taper to that of the end and the centre of the hemisphere is to be so located that the entire tapered portion of the shell and the butt weld are within the hemisphere (*see* Fig. J 3.2).

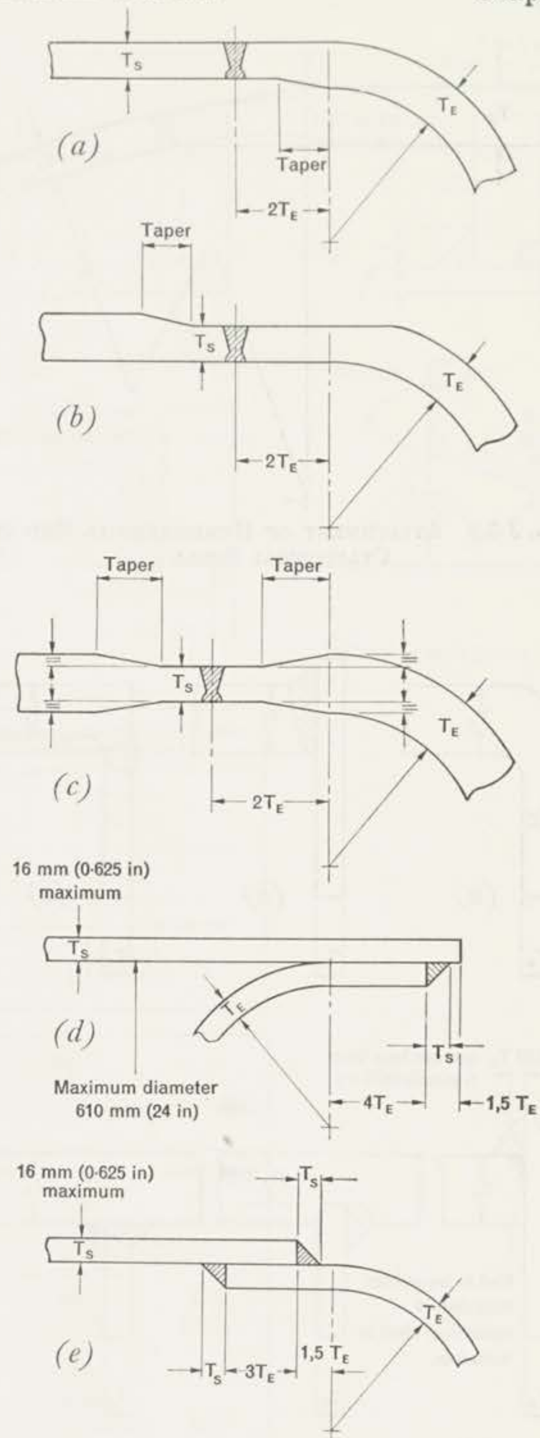
If the hemispherical end is provided with a parallel portion the thickness of this portion is to be not less than that of a seamless or welded shell, whichever is applicable, of the same diameter and material.

Flat End Plates

310 For typical acceptable methods of attaching flat ends to cylindrical and rectangular headers, and to small cylindrical shells; also for the application of the different types, *see* Fig. J 3.3.

The scantlings of flat end plates for circular and rectangular headers are to be determined by the formula in J 221.

The scantlings of flat end plates for small circular pressure vessels and heat exchangers are to be determined by the formula in J 240 taking d as the inside diameter in mm (in) and using a C value of 0,33.



Type	Acceptable for
(d) & (e)	Class 3 pressure vessels
Others	Classes 1, 2/1, 2/2 and 3 pressure vessels

Fig. J 3.1 Typical Acceptable Methods of Attaching Dished Ends to Cylindrical Shells

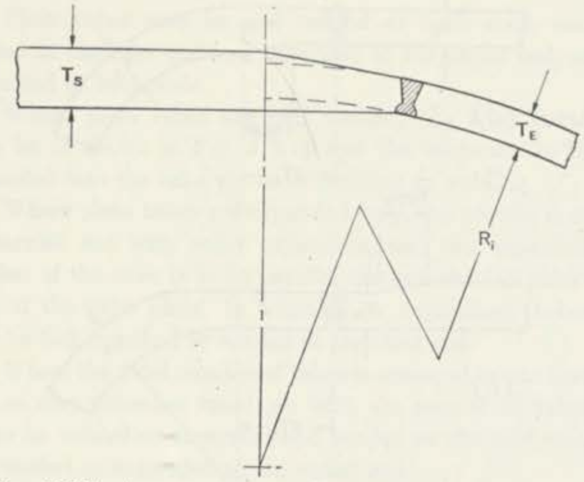


FIG. J 3.2 ATTACHMENT OF HEMISPHERICAL END TO CYLINDRICAL SHELL

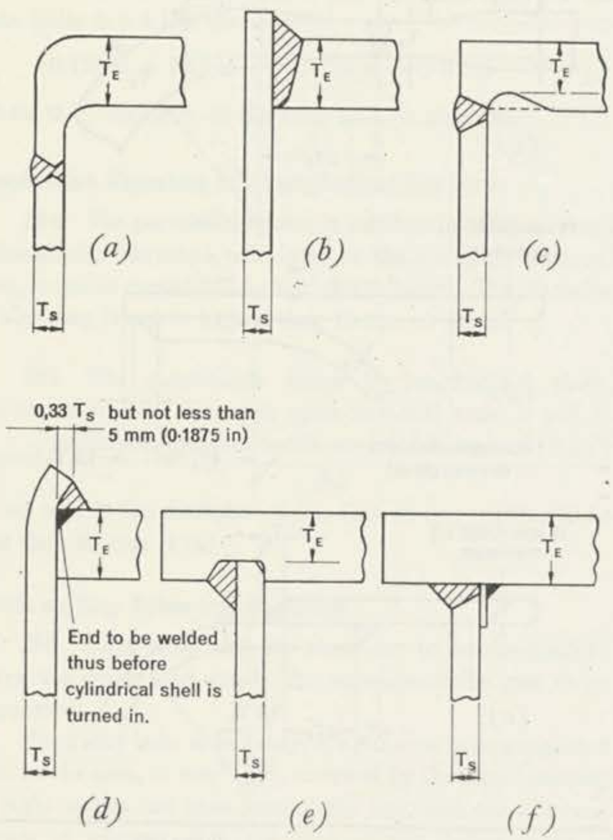


FIG. J 3.3 TYPICAL ACCEPTABLE METHODS OF ATTACHING UNSTAYED FLAT ENDS TO CYLINDRICAL AND RECTANGULAR HEADERS, SMALL PRESSURE VESSELS AND HEAT EXCHANGERS

End types (*a*), (*b*) *and* (*c*) are to be used for headers (*see* Fig. J 2.13)

Standpipes

311 For acceptable methods of attaching flanges to standpipes and service limitations of the various types, *see* Fig. J 3.4.

Where flanges are secured by screwing, the branch and flange are to be screwed with a vanishing thread, and the diameter of the screwed portion of the branch over the thread is not to be less than the outside diameter of the unscrewed branch.

After the flange has been screwed hard home the branch is to be expanded into the flange.

The vanishing thread on a branch is not to be less than three pitches in length and the diameter at the root of the thread is to increase uniformly from the standard root diameter to the diameter at the top of the thread. This may be produced by suitably grinding the dies, and the flange should be tapered out to the same formation.

Welded Attachments to Pressure Vessels

312 Doubling plates with well rounded corners are to be fitted in way of attachments such as lifting lugs, supporting brackets and feet to minimise load concentrations on pressure shells and ends. Compensating plates, pads, brackets and supporting feet are to be bedded closely to the surface before being welded and are to be provided with a "tell-tale" hole not greater than 9,5 mm (0·375 in) in diameter open to the atmosphere to provide for the release of entrapped air during heat treatment of the vessel or as a means of indicating any leakage during hydraulic testing and in service. (*See also* J 512.)

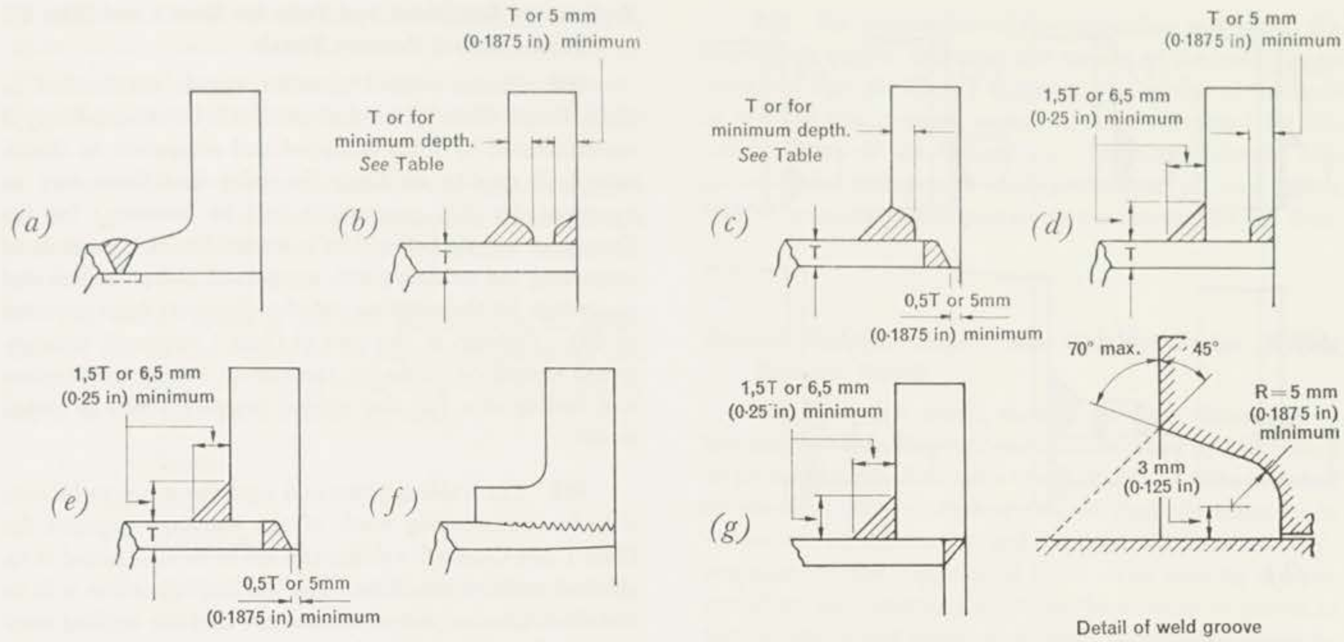
For acceptable methods of attaching standpipes, branches, compensating plates and pads, *see* Fig. J 3.5.

Alternative methods of attachment may be accepted provided details are submitted for consideration.

Fitting of Tubes in Water Tube Boilers

313 The tube holes in drums or headers are to be formed in such a way that the tubes can be effectively tightened in them. Where the tube ends are not normal to the tube plates, there is to be a neck or belt of parallel seating of at least 13 mm (0·5 in) in depth measured in a plane through the axis of the tube at the holes. Where the tubes are practically normal to their plates, this parallel seating is not to be less than 9,5 mm (0·375 in) in depth.

Tubes are to be carefully fitted in the tube holes and secured by means of welding, expanding and belling or by other approved methods. Tubes are to project through the neck or belt of parallel seating by at least 6 mm (0·25 in) and where they are secured from drawing out by means of bellmouthing only the included angle of belling is not to be less than 30°.



Pipe Bore	Minimum Depth of Groove for Flanges (*b*) and (*c*)
13 mm and 19 mm (0·5 in and 0·75 in)	6,5 mm (0·25 in)
25 mm to 38 mm (1 in to 1·5 in)	8 mm (0·3125 in)
50 mm and over (2 in and over)	9,5 mm (0·375 in)

Type of Flange Attachment	Service and Rating			
	Feed, Air, Oil Fuel and other fluids		Steam	
	Pressure kg/cm² (lb/in²)	Temperature °C (°F)	Pressure kg/cm² (lb/in²)	Temperature °C (°F)
(*a*)	All Conditions		All Conditions	
(*b*) & (*c*)	All Conditions		52,5 (750)	454 (850)
(*d*) & (*e*)	52,5 (750)		38,5 (550)	400 (750)
(*f*)	42 (600)	260 (500)	31,5 (450)	
(*g*)	17,5 (250)		17,5 (250)	260 (500)

Fig. J 3.4 Acceptable Methods of Attaching Flanges to Steel Branches or Standpipes

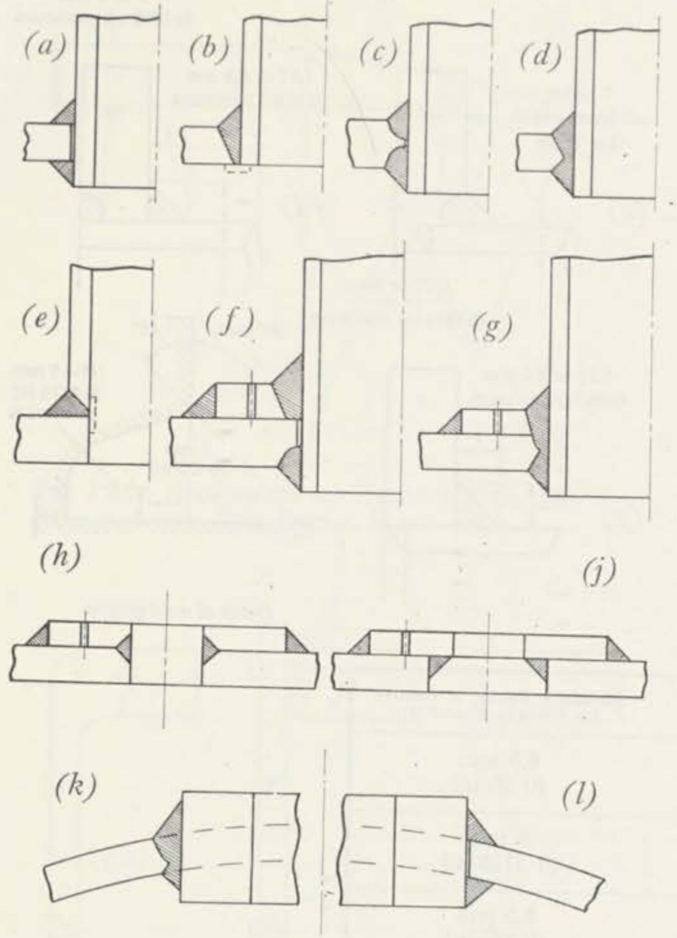


FIG. J 3.5 TYPICAL ACCEPTABLE METHODS OF ATTACHING BRANCHES AND PADS

Types (*a*) and (*l*) attachments are not to be used for openings which require to be compensated. Backing rings may be used with types (*b*) and (*e*)

Section 4

REQUIREMENTS FOR FUSION WELDING

For list of manufacturers of Class 1 *Welded Pressure Vessels, see appendix to this Chapter.*

General

401 The term "fusion weld" is for the purpose of these requirements, applicable to welded joints made by the metal arc process with covered electrodes or other electric arc process in which the arc stream and the deposited metal are shielded from atmospheric contamination. The welding may be done by hand or by machine.

Preliminary Conditions and Tests for Class 1 and Class 2/1 Fusion Welded Pressure Vessels

402 Fusion welded pressure vessels constructed to Class 1 and Class 2/1 requirements will be accepted only if manufactured by firms equipped and competent to undertake high quality welding. In order that firms may be approved for this purpose, it will be necessary for the Surveyors to visit the firm's works for the purpose of inspecting the welding plant, equipment and procedure and to arrange for the carrying out of preliminary tests as stated in 405. Further, in the case of Class 1 approval, arrangements should be made for the survey during construction and testing of a full size welded pressure vessel as stated in 407.

403 The welding plant and equipment are to be suitable for undertaking work of the standard required for Class 1 and Class 2/1 welding and are to be maintained in an efficient working condition. The welding apparatus is to be installed under cover and so arranged that the welding work is carried out in positions free from draughts and adverse weather conditions. The procedure should include the regular systematic supervision of the welding work, and the welding operators are to be subjected by the work's supervisors to periodic tests for quality of workmanship. Records of these tests are to be kept and are to be available for inspection by the Surveyors.

404 The works should be equipped with an efficient testing laboratory which should include apparatus suitable for carrying out tensile, bend and impact tests, micro-examination of specimens and X-ray examination of pressure vessels. The works should also be equipped with a suitable heat-treating furnace having satisfactory means for temperature control.

Alternative arrangements which, in the opinion of the Surveyors, ensure an equally high standard of quality control may be submitted for consideration.

405 Preliminary tests to demonstrate the quality of the welding work are to be carried out by the firm under the supervision of the Surveyors. The test requirements will be based on the grades of steels, and on the welding process to be used. For approval purposes, the grades of rolled steel plates specified in Q 3 shall be grouped as follows:—

Group 1. Carbon and carbon manganese steels 37 to 57 kg/mm^2 ($23 \cdot 5$ to $36 \cdot 2$ ton/in^2).

Group 2. Carbon and carbon manganese steels 52 to 62 kg/mm^2 (33 to $39 \cdot 4$ ton/in^2).

Group 3. Low alloy steels.

Further, the maximum plate thickness which would be approved in pressure vessel construction would depend on the thickness of the test plates used in the preliminary tests; the test plates are, however, to be at least 20 mm (0·75 in) thick.

The test plates and the full size pressure vessel mentioned in 407 are to be representative as regards materials and approximate shell thickness of the production vessels for which approval is desired.

The welded seams of the test plates are to be radiographed and the Surveyors are to select portions of the test plates containing the welded joint from which specimens are to be provided for the following tests:—

1. (*a*) Tensile
   (*b*) Bend
   (*c*) Hardness
   (*d*) Impact } For Class 1 application and for
   (*e*) Fatigue } steels in groups 2 and 3,
2. Micrographs at 100 and 300 magnifications, of weld centre, fusion zone and parent plate.—For Class 1 application and for steels in groups 2 and 3,
3. Macrograph of full section weld,
4. Chemical analysis of deposited weld metal,
5. Chemical analysis of test plates.

NOTE.—Where the welding is carried out by an established and approved process, the fatigue tests and micrographs, 1 (*e*) and 2 above will not in general be required. Further, as an alternative to 5, a guaranteed analysis obtained from the steel makers will be accepted.

406 If a firm intends to manufacture pressure vessels either of a different group of steel, or by means of a different welding process than used in the preliminary tests on which the original approval was based, further tests will be required to cover the proposed welding procedure. In such cases, full details of the material, plate thickness and welding process proposed are to be submitted for consideration when the requirements for further preliminary tests will be indicated.

407 Where firms desire their name to be included in the Society's list of firms recognised by the Committee as experienced manufacturers of Class 1 fusion welded pressure vessels, they should make application at the initial stages of having their works approved. In addition to the preliminary tests, a full size pressure vessel is to be constructed in accordance with the requirements of these Rules for Class 1 fusion welded pressure vessels under the supervision of the Surveyors.

408 On completion of the inspection and tests, the Surveyor's report, including the results of the preliminary tests and also, for Class 1 approval, the results of the tests of the full size pressure vessel, is to be submitted for the consideration of the Committee. The report should also include the radiographs and particulars of any fusion welded pressure vessels previously constructed by the firm.

Routine Tests for Class 1 and Class 2/1 Fusion Welded Pressure Vessels

409 Two test plates, each of sufficient dimensions to provide one complete set of specimens required by 413, should be prepared for each pressure vessel. They should be attached to the shell plate in such a manner that the edges to be welded are a continuation and simulation of the corresponding edges of the longitudinal joint. The welding process, procedure and technique are to be the same as employed in the welding of the longitudinal joint. Test plates are to be so supported, during welding, that warping is reduced to a minimum.

Alternatively, one test plate may be prepared to provide all the test specimens required by 413 and for retest pieces.

410 The test plates are to be straightened before being subjected to heat treatment and for this purpose the test plates may be heated to a temperature below that required for the final heat treatment.

411 Test plates need not be prepared for the circumferential seams, except in cases where a pressure vessel has circumferential seams only, or where the process for welding the circumferential joints is significantly different from that used for the longitudinal joints; when one test plate is to be prepared having a welded joint which so far as possible is a simulation of the circumferential seams. The test plate is to provide all the test specimens required by 413 and for retest pieces.

Where a number of similar vessels are made at the same time it will suffice if test plates are provided for each 30 m (100 ft) of circumferential welded seam.

412 The test plates are to be cut from the shell plate or plates forming the appropriate seam and before being detached are to be stamped by the Surveyor.

When there is insufficient material available on the shell plates for the provision of test plates, acceptance may be given to test plates cut from another plate provided this plate is from the same cast and in the same heat treatment condition.

The thickness of test plates is to be the same as that of the pressure vessel.

413 One set of test specimens is to be cut from the test plates as shown in Fig. J 4.1 or Fig. J 4.2 for Class 1 pressure vessels, or as shown in Fig. J 4.3 or Fig. J 4.4 for Class 2/1 pressure vessels. The results of the tests are to comply with the requirements detailed in 415 to 419.

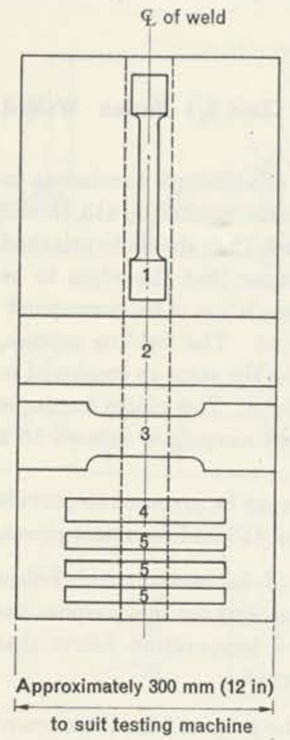


Fig. J 4.1

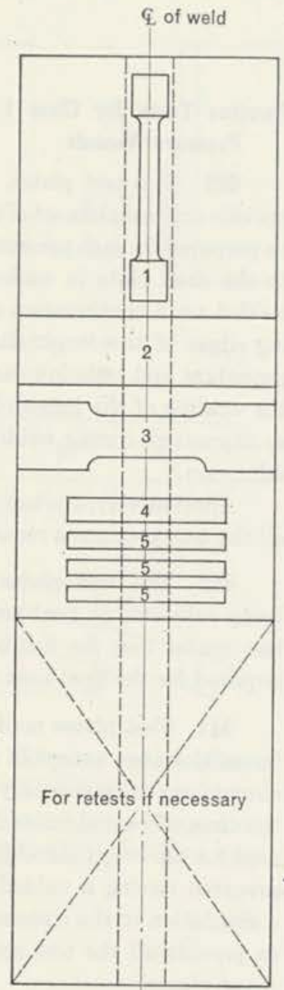


Fig. J 4.2

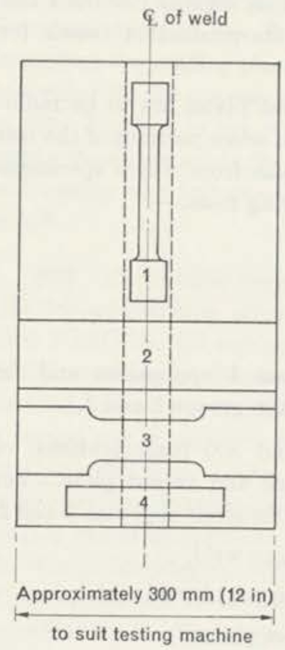


Fig. J 4.3

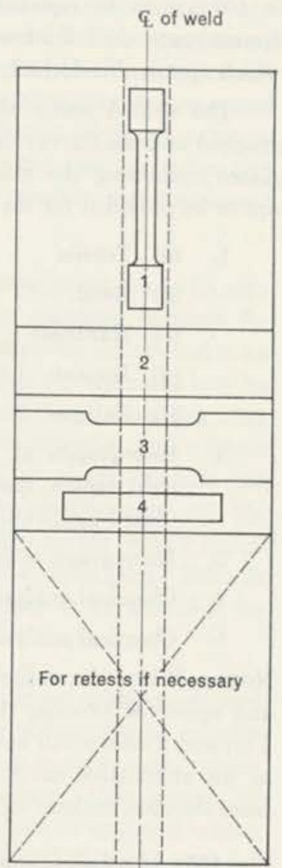


Fig. J 4.4

Test Plates for Class 1 Vessels

1. All weld metal tensile test specimen.
2. Bend test specimens.
3. Tensile test for joint
4. Macro test specimen.
5. Charpy impact test specimens.

Test Plates for Class 2/1 Vessels

1. All weld metal tensile test specimen.
2. Bend test specimens.
3. Tensile test for joint.
4. Macro test specimen.

Retests

414 If any of the tests fail, the reason for the failure is to be investigated and two retest specimens are to be prepared and tested. Where two test plates have been prepared, the retests are to be cut from the second test plate. If it can be shown that the failure of the initial test has resulted from local or accidental defect and the retest values are satisfactory, the retest values may be accepted.

Tensile Test for all Weld Metal. Specimen No. 1

415 One all weld metal tensile specimen is to be taken for Class 1 pressure vessels having a shell thickness not exceeding 70 mm (2·75 in) and for all Class 2/1 pressure vessels. (The latter pressure vessels are restricted by J 107 to a maximum shell thickness of 38 mm (1·5 in)). Where the shell thickness of a Class 1 pressure vessel exceeds 70 mm (2·75 in), two such specimens are to be taken one above the other.

The diameter of the all weld metal test piece at the reduced parallel position is to be not less than 14 mm (0·564 in) except in the case of thin plates where the largest practicable diameter should be used. The gauge length of the test piece is to be five times the diameter.

The dimensions of the all weld metal test specimen are shown in Fig. J 4.5a and their location when two specimens are used in Fig. J 4.5b.

The tensile strength of the weld metal is not to be less than the minimum and not more than 15 kg/mm² (9·25 ton/in²) above the minimum specified for the plate.

The percentage elongation A is not to be less than given by:—

$$A = \frac{100 - R}{2{,}2}$$

where R is the tensile strength in kg/mm² $\left(\frac{\text{lb/in}^2}{1422}\right)$

In addition, this elongation is not to be less than 80 per cent of the equivalent elongation specified for the plate.

Transverse Bend Test. Specimen No. 2

416 Two bend test specimens of rectangular section are to be cut from the test plate transversely to the weld, one to be bent with the outer surface of the weld in tension, and the other with the inner surface in tension.

The specimens are to have a width equal to 1,5 times the thickness of the specimen and the mid-portion is to coincide with the centre line of the weld. The edges are to be rounded to a radius not exceeding 10 per cent of the thickness.

Where the plate thickness does not exceed 30 mm (1·2 in) the thickness of the specimens are to be the full thickness of the plate. Where the plate thickness exceeds 30 mm (1·2 in) the specimens, in all cases, are to have a thickness of 30 mm (1·2 in) and are to be prepared by discarding metal from the surfaces which will be in compression when the test is applied. *See* Figs. J 4.6a and J 4.6b.

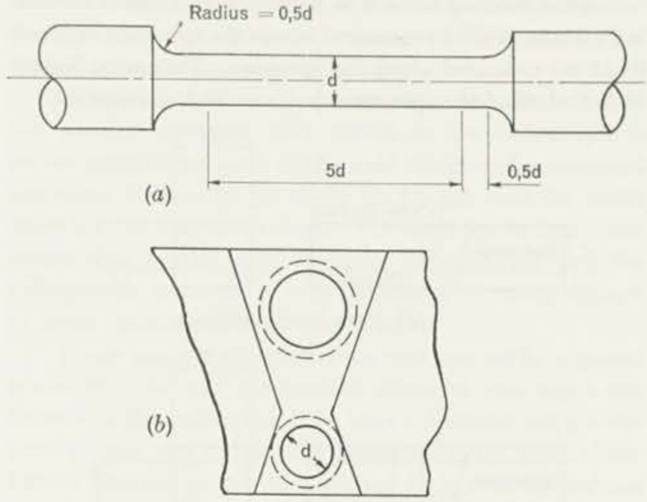


Fig. J 4.5 Specimen No. 1 Tensile Test for all Weld Metal

Where the thickness of the plate permits, the bend specimens may be prepared as shown in Fig. J 4.6c.

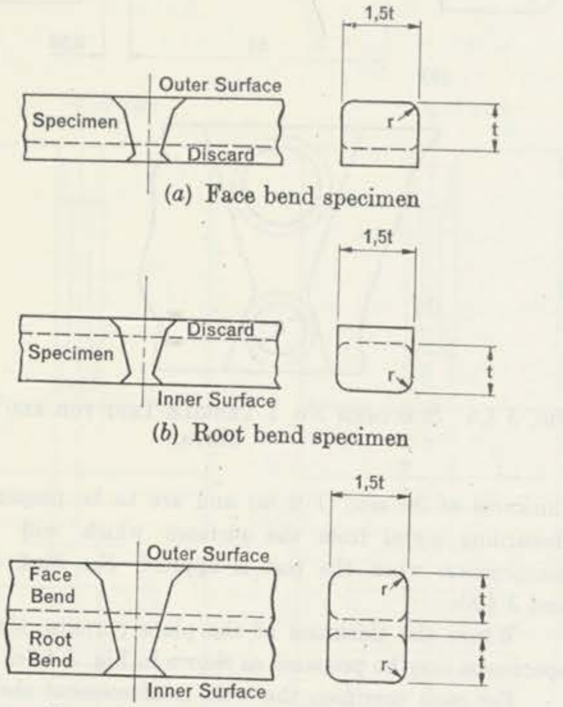
For each specimen the weld reinforcement should be removed by grinding or machining so that the outer and inner surfaces of the weld are flush with the surface of the plate.

The specimen is to be mounted on roller supports with the centre of the weld midway between the supports. A former, with its axis perpendicular to the specimen, is to bend the specimen by pushing it through the clear space between the supports. The diameter of the former and the clear space between the supports will depend on the thickness of the specimens and these dimensions are shown in Table J 4.1 in terms of T the thickness of the specimen.

TABLE J 4.1

Minimum Specified Tensile Strength of Plate		Diameter of Former	Clear Space between Supports
kg/mm²	(ton/in²)		
Under 47	(29·8)	2T	4,2T
47 and under 52	(29·8 and under 33·0)	3T	5,2T
52 and not exceeding 63	(33·0 and not exceeding 40·0)	4T	6,2T

After bending there is to be no crack or defect exceeding 1,5 mm (0·06 in) measured across the specimen or 3 mm (0·12 in) measured along the specimen. Premature failure at the edges of the specimen shall not lead to rejection.



(*a*) Face bend specimen

(*b*) Root bend specimen

(*c*) Face and root bend specimen cut from single piece of plate

FIG. J 4.6 SPECIMEN NO. 2 BEND TEST

Tensile Test for Joint. Specimen No. 3

417 One reduced section tensile test specimen is to be cut transversely to the weld, or in thick plate, as many tensile test specimens as may be necessary to investigate the tensile strength throughout the whole thickness of the joint. The weld reinforcement should be removed by grinding or machining so that the outer and inner surfaces of the weld are flush with the surface of the plate. The dimensions of the reduced section tensile test specimens are shown in Fig. J 4.7. The width B at the reduced section is to be at least 25 mm (1 in).

Where the plate thickness exceeds 30 mm (1·2 in) the tensile test may be effected on several reduced-section specimens each with a thickness of at least 30 mm (1·2 in) and a width at the effective cross-section of at least 25 mm (1 in).

The tensile strength obtained is not to be less than the minimum specified tensile strength for the plate material.

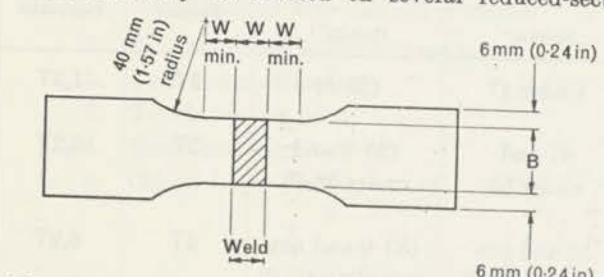


FIG. J 4.7 SPECIMEN NO. 3 TENSILE TEST FOR JOINT

Macro Specimen. Specimen No. 4

418 Macro etching of a complete cross-section of the weld including the heat affected zone is to show a satisfactory penetration and an absence of lack of fusion, significant inclusions or other defects.

Should there be any doubt as to the condition of the weld as shown by macro etching, the area concerned is to be microscopically examined.

Notched Bar Impact Test. Specimen No. 5. Class 1 only.

419 Three Charpy V-notch impact test specimens are to be cut transversely to the weld, parallel to the plate surface and at mid-plate thickness. The notch is to be cut at approximately the centre of the weld and the axis of the notch is to be perpendicular to the surface of the plate.

The dimensions of the specimens are as shown in Fig. J 4.8.

The minimum result obtained from the Charpy V-notch test specimens is not to be less than 2,77 kg m (20 ft lb) when the temperature of the specimen at the time of test does not exceed 50°C (122°F).

Where it is proposed to use impact tests other than Charpy V-notch tests, details should be submitted for consideration.

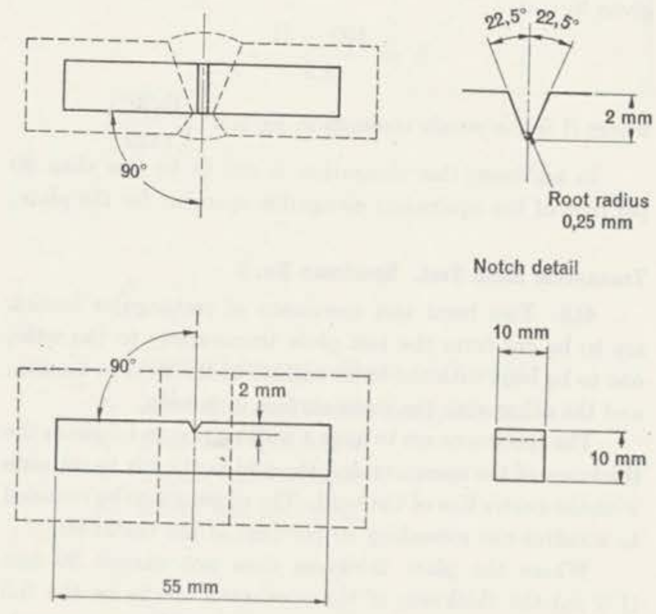


FIG. J 4.8 SPECIMEN NO. 5 CHARPY V-NOTCH IMPACT TEST SPECIMEN

The foregoing impact tests are not applicable to pressure vessels operating at low metal temperatures, and for such cases the results of the weld metal impact tests will be specially considered (*see* J 703).

NON-DESTRUCTIVE EXAMINATION

Radiographic Examination

420 The extent of the radiographic examination of the welded seams of Class 1 and Class 2/1 pressure vessels are to be as follows:—

(*a*) Class 1 Pressure Vessels. All butt welded seams in drums, shells, headers and pipes and tubes over 170 mm (6·625 in) outside diameter, together with the test plate or plates, are to be subjected to 100 per cent radiographic examination. For circumferential butt welds in extruded connections, pipes, tubes, headers and other tubular parts 170 mm (6·625 in) outside diameter and less, 10 per cent of the total number of welds are to be radiographed. *See also* 426.

(*b*) Class 2/1 Pressure Vessels. Spot radiographs are to be taken at selected regions of each main seam. The test plate or plates are to be fully radiographed and at least 10 per cent of the length of each main seam is to be so examined. *See also* 427.

Butt welds in furnaces, combustion chambers and other pressure parts for fired pressure vessels under external pressure, are to be subject to spot radiographic examination.

Where the surface finish of any weld which has to be radiographed is such that it will prevent accurate radiographic examination, the surface is to be machined or ground to provide a smooth contour to the Surveyor's satisfaction.

421 Lead type is to be fixed to the plate adjacent to the weld so that each radiograph is marked in such a way that the corresponding portion of the welded seam can be readily and accurately identified.

The length of weld covered by each exposure is to be such that the metal thickness along the incident beam at the extremity of the exposure is not to exceed the actual thickness by more than 10 per cent.

422 Image quality indicators (penetrameters) of an approved type are to be placed at each end of each radiograph and on the surface of the plate facing the source of radiation.

Image quality indicators of the step hole type are to be placed alongside the welded seam parallel to its length and are to have a hole in each step of a diameter corresponding to its thickness at that step or are to have some similar device whereby the step thickness can be identified when the radiographic film is examined.

The radiographic technique employed is to be such that the smallest diameter hole visible in the radiograph is not to exceed 3 per cent of the weld thickness for welds not exceeding 50 mm (2 in) thick, or 2,5 per cent for welds exceeding 50 mm (2 in) thick. The steps are to bear these proportions to the weld thickness radiographed and the radiographic technique is to be capable of revealing changes of metal thickness of these percentages.

Image quality indicators of the wire type are to be placed across the weld and the smallest diameter wire which can be seen in the radiograph is to have a diameter not greater than 1,5 per cent of the weld thickness, if the weld thickness is between 10 mm (0·4 in) and 50 mm (2 in) and not greater than 1,25 per cent of the weld metal thickness if the thickness exceeds 50 mm (2 in) up to 200 mm (7·875 in).

The use of gamma rays may be permitted in certain circumstances when details should be submitted for consideration and approval.

423 Radiographs are to be examined by the Surveyors on the original films using a viewing device of suitable illuminating power.

Ultrasonic Examination

424 In Class 1 pressure vessels where the plate thickness exceeds 65 mm (2·5 in), ultrasonic examination may be accepted as an alternative to radiographic examination. Such examination is to be affected by an approved operator using an approved technique incorporating autographic recording of flaw signals and coupling reliability. Supplementary examination by radiography at selected locations may be required in certain cases.

Magnetic Crack Detection

425 In Class 1 and Class 2/1 pressure vessels the welds on standpipes, compensating plates, stubs and branches, etc., of ferritic steels, which have not been radiographed are to be magnetically crack detected at the rate of 10 per cent of such welds. This rate may be increased or decreased at the discretion of the Surveyors. For non-magnetic materials dye penetrant examination will be accepted.

Repairs to Welded Seams

426 In the case of Class 1 pressure vessels when non-destructive tests show unacceptable defects in the welded seams, the defects are to be repaired and are to be shown by further non-destructive tests to have been eliminated to the Surveyor's satisfaction.

427 In the case of Class 2/1 pressure vessels, when a spot radiograph reveals unacceptable defects in a welded seam, at least two further radiographs are to be made in the length of weld represented by the first radiograph in locations selected by the Surveyor. If these reveal no further unacceptable defects, the defects revealed by the first radiograph are to be repaired and re-radiographed. If the check radiographs reveal unacceptable defects either:—

(*a*) the whole length of weld represented is to be cut out and re-welded, then subjected to spot radiography as if it were a new weld, and the original test plates associated with the weld are to be similarly treated, *or*

(*b*) the whole length of weld represented is to be radiographed. Unacceptable defects are to be repaired and are to be shown by radiography to have been eliminated.

Preliminary Conditions and Tests for Class 2/2 Fusion Welded Pressure Vessels

428 Pressure vessels made in accordance with Class 2/2 requirements will be accepted only if constructed by firms whose works are properly equipped to undertake the welding of pressure vessels of this Class.

The welding plant is to be installed under cover and is to be maintained in an efficient working condition and adequate supervision of the welding work is to be provided.

It will be necessary for the Surveyors to visit the firm's works for the purpose of inspecting the welding plant, equipment and procedure and to arrange for the carrying out of preliminary tests similar to those described in 436, 437 and 438.

On completion of the inspection and tests, the Surveyor's report including the results of the preliminary tests and particulars of the fusion welded pressure vessels previously constructed by the firm are to be submitted for the consideration of the Committee.

Routine Tests for Class 2/2 Fusion Welded Pressure Vessels

429 Two test plates each of sufficient dimensions to provide one complete set of specimens required by 434 should be prepared for each pressure vessel. They should be attached to the shell plate in such a manner that the edges to be welded are a continuation and simulation of the corresponding edges of the longitudinal joint. The welding process, procedure and technique are to be the same as employed in the welding of the longitudinal joint. Test plates are to be so supported during welding that warping is reduced to a minimum.

Alternatively, one test plate may be prepared to provide all the test specimens required by 434 and for retest pieces.

430 In cases where a number of Class 2/2 pressure vessels are made concurrently at the same works, and the plate thicknesses do not vary by more than 5 mm (0·19 in), each 37 m (120 ft) of welded seam, longitudinal plus circumferential, may be regarded as equivalent to one pressure vessel, the required number of test specimens being provided accordingly.

In these cases the thickness of the test plates is to be equal to that of the thickest shell plate used in the construction of the pressure vessels.

431 The test plates are to be straightened before being subjected to heat treatment and for this purpose the test plates may be heated to a temperature below that required for the final heat treatment.

432 Test plates need not be prepared for the circumferential seams, except in cases where a pressure vessel has circumferential seams only, or where the process for welding the circumferential joints is significantly different from that used for the longitudinal joints, when one test plate is to be prepared having a welded joint which, so far as possible, is a simulation of the circumferential seams. The test plate is to provide all the test specimens required by 434 and for retest pieces.

Where a number of similar vessels are made at the same time, it will suffice if test plates are provided for each 30 m (100 ft) of circumferential welded seam.

433 The test plates are to be cut from the shell plate or plates forming the appropriate seam and before being detached are to be stamped by the Surveyor.

When there is insufficient material available on the shell plates for the provision of test plates, acceptance may be given to test plates cut from another plate provided this plate is from the same cast and in the same heat treatment condition.

The thickness of test plates is to be the same as that of the pressure vessel.

434 One set of test specimens is to be cut from the test plates as shown in Fig. J 4.9 or Fig. J 4.10. The results of the tests are to comply with the requirements detailed in 436, 437 and 438.

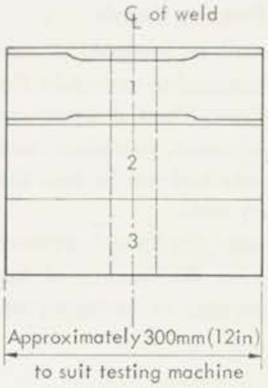


FIG. J 4.9

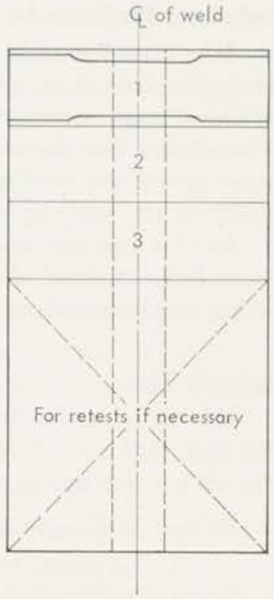


FIG. J 4.10

TEST PLATES FOR CLASS 2/2 VESSELS

1. Tensile test for joint.
2. Bend test specimens.
3. Nicked bend test specimen.

435 If any of the tests fail, the reason for the failure is to be investigated and two retest specimens are to be prepared and tested. Where two test plates have been prepared, the retests are to be cut from the second test plate. If it can be shown that the failure of the initial test has resulted from local or accidental defect and the retest values are satisfactory, the retest values may be accepted.

Tensile Test for Joint

436 The shape and preparation of the specimen are to conform to the requirements of 417.

The tensile strength obtained is not to be less than the minimum specified tensile strength for the plate material.

Transverse Bend Tests

437 The shape and preparation of the specimens and the procedure for testing are to comply with the requirements of 416 as applicable to the grade of steel permitted by Table J 1.1.

Nicked Bend Tests

438 The specimen is to have a slot cut into each side on the centre line of the weld and perpendicular to the plate surface. The specimen is then to be broken in the weld and the fracture is to reveal a sound homogeneous weld, substantially free from slag inclusions, porosity and coarse crystallinity.

Post-Welding Heat Treatment

Note.—For heat treatment on completion of the forming of shell sections and end plates, see J 504.

439 Depending upon the grade of steel and plate thickness, Class 1, Class 2/1 and Class 2/2 pressure vessels, where indicated in Table J 4.2, are to be efficiently heat treated on completion of the welding of the seams and of all attachments to the shell and ends and before the hydraulic test is carried out.

TABLE J 4.2

Grade of Steel	Tensile Range		Plate thicknesses at and above which post-welding heat treatment is required		
	kg/mm^2	(ton/in^2)	Class 1	Class 2/1	Class 2/2
Carbon and Carbon-manganese	37–47	(23·5–29·8)	20 mm (0·75 in)	*See* Note below	*See* Note below
	42–52	(26·7–33·0)	20 mm (0·75 in)	32 mm (1·25 in)	32 mm (1·25 in)
	47–57	(29·8–36·2)	20 mm (0·75 in)	25 mm (1 in)	—
	52–62	(33·0–39·4)	20 mm (0·75 in)	20 mm (0·75 in)	—
Low alloy steels	—	—	All thicknesses to be heat treated	—	—

NOTE.—The maximum thickness of Class 2/1 and Class 2/2 pressure vessels is limited to 38 mm (1·5 in) and heat treatment is not required for carbon and carbon-manganese steels in the tensile range 37–47 kg/mm^2 (23·5–29·8 ton/in^2).

440 Heat treatment is to be carried out in a properly constructed furnace which is efficiently maintained and has adequate means for temperature control and is fitted with pyrometers which will measure and record the temperature of the furnace charge. The heat treatment is to consist of heating the vessel slowly and uniformly to a suitable stress relieving temperature, soaking for a suitable period, followed by cooling slowly and uniformly in the furnace to a temperature not exceeding 400°C (750°F) and subsequently cooling in a still atmosphere. The temperature and soaking periods are to be selected which will relieve residual stress without undue reduction of the properties of material.

Recommended soaking temperatures and periods are given in Table J 4.3.

In cases where other materials are used for pressure vessel construction, full details of the proposed heat treatment are to be submitted for consideration.

441 Where pressure vessels are of such dimensions that the whole length cannot be accommodated in the furnace at one time, the pressure vessels may be heated in sections provided sufficient overlap is allowed to ensure the heat treatment of the entire length of the longitudinal seam.

442 Test plates should be heat treated in the same furnace and at the same time as the pressure vessels which they represent. In special cases, however, it may be permissible to heat treat the test plates separately from the pressure vessels provided the Surveyor is satisfied with the means adopted to ensure that the following factors will be the same for the pressure vessels as for their respective test plates:—

Rate of heating,
Maximum temperature,
Time held at maximum temperature,
Conditions of cooling.

443 Where it is proposed to adopt special methods of heat treatment full particulars are to be submitted for consideration. In such cases it may be necessary to carry out tests to show the effect of the proposed heat treatment.

Preliminary Conditions for Class 3 Pressure Vessels

444 Class 3 pressure vessels will be accepted if constructed by firms whose works are equipped to undertake the welding of pressure vessels of this type. The Surveyors are to be satisfied that the welding equipment, procedure and supervision of the work are adequate and are to test the quality of the welds by preliminary tests.

Routine weld tests are not required for Class 3 pressure vessels but occasional check tests on the quality of the welding may be carried out at the discretion of the Surveyors.

Hydraulic Test

445 Boilers and unfired pressure vessels, together with their components, are to withstand the following hydraulic tests without any sign of weakness or defect.

1. Boilers, including Steam Heated Steam Generators.

Having regard to the variation in the types and design of boilers, the hydraulic test may be carried out by either of the methods indicated below:—

(i) The boiler on completion is to be tested to a pressure of 1,5 times the design pressure, *or*

(ii) (*a*) Where construction permits, all components of the boiler are to be tested on completion of the work including heat treatment to 1,5 times the design pressure. In the case of components such as drums or headers, which are to be drilled for tube holes, the test may be made before drilling the tube holes but is to be after the attachment of standpipes, stubs and similar fittings and also after heat treatment has been carried out,

(*b*) Provided all the components have been tested as in (*a*) above, each completed boiler after assembly is to be tested to 1,25 times the design pressure.

Where any of the components have not been tested as in (*a*) above, each completed boiler after assembly is to be tested to 1,5 times the design pressure.

TABLE J 4.3

Type of Steel	Soaking Temperatures	Time at Temperature per 25 mm (1 in) of Thickness
Carbon Carbon-manganese	580–620°C (1080–1150°F)	1 hour—min. period 1 hour
1 Cr ½ Mo	620–660°C (1150–1220°F)	1 hour—min. period 2 hours
2¼ Cr 1 Mo	650–690°C (1200–1270°F)	2 hours—min. period 2 hours

2. Unfired Pressure Vessels.

Unfired pressure vessels are to be tested on completion to a pressure, P_T, which is to be determined by the following formula:—

$$P_T = 1{,}3 \frac{f_{100}}{f_d} \frac{T}{(T-C)} P$$

but is in no case to exceed $1{,}5 \frac{T}{(T-C)} P$

where P_T = test pressure, in kg/cm^2 (lb/in^2),

P = design pressure, in kg/cm^2 (lb/in^2),

T = nominal thickness of shell as indicated on the plan, in mm (in),

C = corrosion allowance to be taken as 0,75 mm (0·03 in),

f_{100} = allowable stress at 100°C (212°F), in kg/cm^2 (lb/in^2),

f_d = allowable stress at design temperature, in kg/cm^2 (lb/in^2).

Section 5

MANUFACTURE AND WORKMANSHIP

FUSION WELDED PRESSURE VESSELS

Note:—The following requirements are applicable to all classes of fusion welded pressure vessels except where otherwise indicated.

Electrodes

501 Electrodes intended for use in the construction of pressure vessels are to be stored in a dry place. In order to ensure that the quality of electrodes is being consistently maintained they are to be subjected to a regular system of periodic testing and inspection. Where routine tests are frequently carried out in respect of pressure vessels made in the normal course of production, such tests may be regarded as meeting the requirements of this paragraph.

Welding Equipment

502 All welding plant and auxiliary equipment is to be maintained in good working order and adequate means of measuring current are to be provided. In the case of machine welding, means are to be provided for measuring the arc voltage. All electrical plant used in connection with the welding operation is to be adequately earthed.

Plate Cutting

503 Plates are to be cut to size and shape by machine flame cutting and/or machining. Where the plate thickness does not exceed 25 mm (1 in) cold shearing may be used provided that the sheared edge is cut back by machining or chipping for a distance of one quarter of the plate thickness but in no case less than 3 mm (0·125 in).

All plate edges, after cutting and before carrying out further work upon them are to be examined for laminations, and also to ensure that any sheared edges are free from cracks. Visual methods may be supplemented by other techniques at the discretion of the Surveyor.

Forming Shell Sections and End Plates

504 Plates for shell sections and end plates are to be formed to the required shape by any process that will not impair the quality of the material. Tests to demonstrate the suitability of a process may be required at the discretion of the Surveyors.

Shell plates are to be formed to the correct contour up to the extreme edges of the plate. As far as possible, hot and cold forming is to be done by machine; forming by hammering with or without local heating is not to be employed.

All plates which have been hot formed or locally heated for forming are to be normalised on completion of this operation. If, however, hot forming is carried out entirely at a temperature within the normalising range, subsequent heat treatment will not be required for carbon steels. In both instances alloy steels may, in addition, require to be tempered.

All plates which have been cold formed to an internal radius less than 10 times the plate thickness are to be given an appropriate heat treatment.

Preparation of Plate Edges and Openings for Welding

505 Welding preparations and openings of the required shapes may be formed by the following methods:—

(i) Machining, chipping or grinding; chipped surfaces which will not be covered with weld metal are to be ground smooth after chipping.

(ii) Flame cutting.

Special examination will be required for cracks on the cut surfaces and the heat affected zones in flame cut alloy or high carbon steels; preheating may be required in order to ensure satisfactory results when flame cutting.

Any material damaged in the process of cutting plates to size or forming welding grooves is to be removed by machining, grinding or chipping back to sound metal. Surfaces which have been flame cut are to be cut back by machining or grinding so as to remove all burnt metal, notches, slag and scale, but slight discolouration of machine flame cut edges on mild steel is not to be regarded as detrimental. If alloy steels are prepared by flame cutting the

surface is to be dressed back by grinding or machining for a distance of at least 1,6 mm (0·0625 in) unless it has been shown that the material has not been damaged by the cutting process.

506 After edges of the plates have been prepared for welding they are to be carefully examined for flaws, cracks, laminations, slag inclusions or other defects.

507 Care is to be taken to ensure that the weld preparations are correctly profiled.

Assembly of Plates for Welding

508 The plates are to be assembled and retained in position for welding by any suitable method; tack welds, where used, are to be removed so that they do not become part of the seam. Correction of irregularities is not to be carried out by hammering.

Where a root gap is specified the edges of butt welds are to be held so that the correct gap is maintained during welding.

Where welded-on bridge pieces or other aids to fabrication are used, care is to be taken that the surfaces of the material are not left in a damaged condition after the attachments have been removed. Any necessary removal of attachments and rectification of scars by welding is to be undertaken before applying post-weld heat treatment.

Butt Welds in Plates of Equal Thickness

509 The surfaces of the plates at the longitudinal or circumferential seams are not to be out of alignment with each other at any point by more than 10 per cent of the plate thickness, but in no case is the misalignment to exceed 3 mm (0·125 in) for longitudinal seams or 4 mm (0·156 in) for circumferential seams.

Butt Welds in Plates of Unequal Thickness

510 Where a drum is constructed of plates of different thicknesses (tube plate and wrapper plate), the plates are to be arranged so that their centre lines form a continuous circle. For the longitudinal seams, the thicker plate is to be equally chamfered inside and outside by machining over a circumferential distance not less than twice the difference in the thicknesses so that the two plates are of equal thickness at the position of the longitudinal weld. For the circumferential seam, the thicker plate is to be similarly prepared over the same distance longitudinally.

For the circumferential seam, where the difference in the thicknesses is the same throughout the circumference, the thicker plate is to be reduced in thickness by machining to a taper for a distance not less than four times the offset so that the two plates are of equal thickness at the position of the circumferential weld. A parallel portion may be provided between the end of the taper and the weld edge preparation; alternatively, if so desired, the width of the weld may be included as part of the smooth taper of the thicker plate.

The surfaces of the plates at the longitudinal or circumferential seams are not to be out of alignment with each other at any point by more than 10 per cent of the thickness of the thinner plate, but in no case is the misalignment to exceed 3 mm (0·125 in) for longitudinal seams or 4 mm (0·156 in) for circumferential seams.

Plates Welded Prior to Forming

511 Seams in plates may be welded prior to forming provided on completion of forming and subsequent heat treatment they meet the specified mechanical test requirements and that they are examined radiographically throughout their length after forming (*see*, however, J 424). After forming, the surfaces of such seams in alloy steel parts, also carbon steel parts over 25 mm (1 in) in thickness, are to be ground smooth and inspected for cracks by magnetic crack detection, dye penetrants or other means at the discretion of the Surveyor.

Attachments and Fittings

512 All lugs, brackets, branches, manhole frames and reinforcements around openings and other members are to conform to the shape of the surface to which they are attached.

The attachment by welding of such fittings to the main pressure shell after post-weld heat treatment is not permitted, except where the material involved is mild steel when welding will only be permitted provided it is necessitated by the method of construction being employed and prior approval of the Surveyor must be obtained before any welding is carried out. In no circumstances is any welding to be done after heat treatment on vessels made of carbon or carbon-manganese steel with tensile strength exceeding 52 kg/mm² (33 ton/in²) or of alloy steel.

When the fittings referred to above (*see also* J 312), together with flats and other attachments for supporting internal and external components, are welded to the main pressure shell, the welding is to be of comparable standard to that required for the vessel and the material used is to be of compatible composition.

The finish of all welds attaching pressure parts and non-pressure parts to the main pressure shell is to be such as to permit satisfactory examination of the welds. In the case of Class 1 pressure vessels these welds are to be ground smooth, if necessary, to provide a suitable finish for crack detection tests which are to be carried out to the Surveyor's satisfaction on completion of the hydraulic test.

Welding of Main Seams

513 When welding with the manual metal arc and submerged arc welding processes, the following requirements are to be applied. When other processes are utilised it may be necessary to modify or amplify these precautions to ensure satisfactory workmanship.

(*a*) All surfaces to be welded are to be thoroughly cleaned of scale, rust, oil or other foreign matter down to a clean surface for a distance of at least 12,5 mm (0·5 in) from the welding edge. Welding grooves are to be similarly cleaned.

(*b*) Unless otherwise approved seams are to be welded from both sides of the plate. When manual arc welding is employed, the metal at the bottom of the first side is to be removed by grinding, chipping, machining or other approved methods so as to provide clean sound metal on which to deposit the subsequent welds.

The welding procedure for a butt joint welded from one side of the plate is to provide complete fusion. Special care is to be taken to ensure that the root is properly fused and that distortion due to the contraction of the weld metal is minimised.

Backing strips, if used, are to be of the same nominal composition as the plates to be welded and where practicable are to be removed and the surface dressed smooth by grinding prior to radiography.

The roots of butt joints and seams welded from one side of the plate are to be dressed smooth by grinding and before radiographic examination. The dressed surfaces are to be examined for root defects.

(*c*) Each run of weld metal is to be thoroughly cleaned and all slag removed before the next run is deposited.

(*d*) After welding has been stopped for any reason, care is to be taken in restarting to ensure that the previously deposited weld metal is thoroughly clean and free from slag, and that there is proper penetration into the plates and the previously deposited weld metal.

(*e*) Welding is to be carried out in the downhand horizontal position. In the case of circumferential seams means are to be adopted to ensure compliance with this requirement.

(*f*) Fillet welds are to be made so as to ensure proper fusion and penetration of the weld metal at the root of the fillet.

(*g*) Not less than two runs of metal are to be deposited at each weld affixing branch pipes, flanges and seatings.

(*h*) The arc is to be struck only on those parts of the parent metal where the weld metal is to be applied or of the welding metal already deposited.

(*j*) Preheating is to be employed when necessitated by the joint restraint, thickness of the plate, and composition of the material to be welded.

(*k*) On completion of the welding, the seams are to be thoroughly examined before being dressed or machined. Parts showing evidence of blow-holes, slag inclusions, unsatisfactory penetration, porosity, or any other defect are to be cut out and rewelded, and undercutting made good.

The outer surfaces of the welds may be flush with the surfaces of the plates joined, but no objection will be raised if the total thickness at the centre of the weld is greater than the thickness of the plates, provided the change of section is gradual.

(*l*) In cases where it is proposed to adopt fusion welding processes in which it may not be possible to comply fully with the foregoing requirements regarding technique, full particulars are to be submitted for consideration.

Tolerances for Cylindrical Shells

514 The shell sections of completed vessels are to be circular within the limits defined in 516. Measurements are to be made to the surface of the parent plate and not to a weld, fitting or other raised part.

Shell sections are to be measured for out-of-roundness either when laid flat on their sides or when set up on end. When the shell sections are checked whilst lying on their sides, each measurement for diameter is to be repeated after turning the shell through 90° about its longitudinal axis. The two measurements for each diameter are to be averaged and the amount of out-of-round calculated from the average values so determined.

There are to be no flats or peaks at welded seams and any local departure from circularity is to be gradual.

515 The external circumference of the completed shell is not to depart from the calculated circumference (based upon nominal inside diameter and the actual plate thickness) by more than the following amounts:—

TABLE J 5.1

Outside Diameter (Nominal inside diameter plus twice actual plate thickness)	Circumferential Tolerance
300 mm (12 in) up to and including 600 mm (24 in)	± 5 mm (0·1875 in)
Over 600 mm (24 in)	± 0,25 per cent

516 In assessing the out-of-roundness of pressure vessels, the difference between the maximum and minimum internal diameters measured at one cross-section is not to exceed the amount given in Table J 5.2.

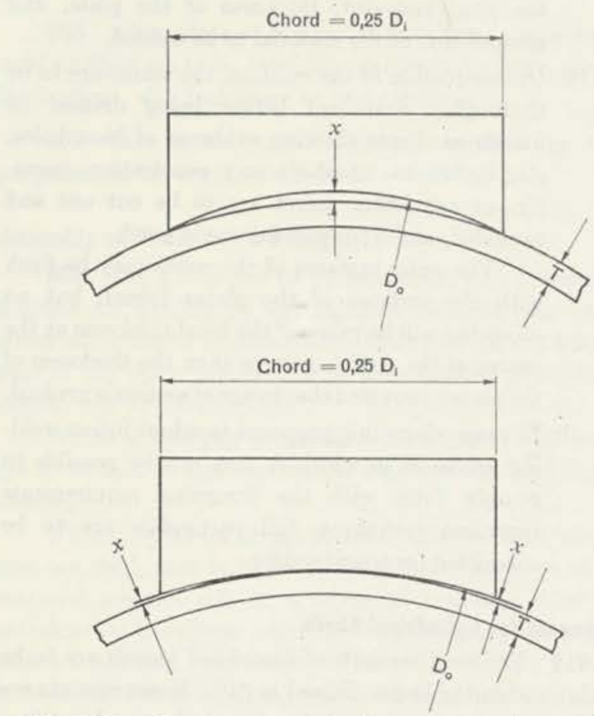


FIG. J 5.1 TOLERANCES FOR CYLINDRICAL SHELLS

The profile, measured on the inside or outside of the shell by means of a gauge of the designed form of the shell and having a length equal to one quarter of the internal diameter of the vessel, is not to depart from the designed form by more than the amount given in Table J 5.2. (This amount corresponds to x in Fig. J 5.1).

Section 6

MOUNTINGS AND FITTINGS

MOUNTINGS AND FITTINGS FOR CYLINDRICAL AND VERTICAL BOILERS AND UNFIRED STEAM GENERATORS

General

601 Valves over 38 mm (1·5 in) diameter are to be fitted with outside screws and the covers are to be secured by bolts or studs. All valves are to be arranged to be shut with a right-hand (clockwise) motion of the wheels.

602 All valves and cocks connected to the boiler are to be such that it is seen without difficulty whether they are open or shut. Where boiler mountings are secured by studs, the studs are to have a full thread holding in the plate for a length of at least one diameter. If the stud hole penetrates

TABLE J 5.2

Nominal Internal Diameter of Vessel		Difference between Max. and Min. Diameters	Maximum Departure from Designed Form
Over	Up to and including		mm (in)
—	300 mm (12 in)	1,0 per cent of internal diameter	1,2 (0·046 88)
300 mm (12 in)	460 mm (18 in)		1,6 (0·0625)
460 mm (18 in)	600 mm (24 in)		2,4 (0·093 75)
600 mm (24 in)	900 mm (36 in)		3,2 (0·125)
900 mm (36 in)	1220 mm (48 in)		4,0 (0·156 25)
1220 mm (48 in)	1520 mm (60 in)		4,8 (0·1875)
1520 mm (60 in)	1900 mm (75 in)		5,6 (0·218 75)
1900 mm (75 in)	2300 mm (90 in)	19 mm (0·75 in)	6,4 (0·25)
2300 mm (90 in)	2670 mm (105 in)		7,2 (0·281 25)
2670 mm (105 in)	3950 mm (156 in)	19 mm (0·75 in)	8,0 (0·3125)
3950 mm (156 in)	4650 mm (186 in)	19 mm (0·75 in)	0,2 per cent of vessel diameter
4650 mm (186 in)		0,4 per cent of vessel internal diameter	

the whole thickness of the plate the stud is to be screwed right through the plate and is to be fitted with a nut inside the boiler. Where bolts are used for securing mountings they are to be screwed right through the plate with their heads inside the boiler.

603 Where a superheater is fitted which can be shut off from the boiler it is to be provided with a separate safety valve fitted with easing gear. The valve as regards construction is to comply with the regulations for ordinary safety valves, but the easing gear may be fitted to be workable from the the stokehold only. The superheater is also to be fitted with a drain valve or cock to free it from water when necessary.

604 Safety valve chests and other boiler and superheater mountings subjected to pressures exceeding 10,5 kg/cm² (150 lb/in²) or to steam temperatures exceeding 218°C (425°F), and boiler blow down fittings, are to be made of steel or other approved material.

Safety Valves

605 Boilers and unfired steam generators are to be fitted with not less than two safety valves, each having a minimum diameter of 38 mm (1·5 in), but those having a total heating surface of less than 9,3 m² (100 ft²) may have one valve not less than 50 mm (2 in) diameter.

606 The valves, spindles, springs and compression screws are to be so encased and locked that the safety valves and pilot valves, after setting to the working pressure, cannot be tampered with or overloaded in service; the spring casing of superheater safety valves should be ventilated or other arrangement provided to protect the springs from excessive temperature.

Valves are to be so designed that in the event of fracture of springs they cannot lift out of their seats. For safety valves operating at pressures below 17,5 kg/cm² (250 lb/in²) it should, in general, be possible for the valves to be turned round on their seats by hand.

Easing gear is to be provided for lifting the safety valves and is to be operable by mechanical means at a safe position from the boiler or engine room platforms.

Safety valves are to be made with working parts having ample clearances to ensure complete freedom of movement. Valve seats are to be effectively secured in position. Any adjusting devices which control discharge capacity are to be positively secured so that the adjustment will not be affected when the safety valves are dismantled at surveys.

607 All the safety valves of each boiler and unfired steam generator may be fitted in one chest, which is to be separate from any other valve chest and is to be connected directly to the shell by a strong and stiff neck, the passage through which is not to be of less cross-sectional area than the aggregate area of the safety valves in the chest in the case of full lift valves and one-half of that area in the case of other valves. For the meaning of aggregate area, *see* 608.

Each safety valve chest is to be drained by a pipe fitted to the lowest part and led with a continuous fall to the bilge or to a tank, clear of the boilers. No valves or cocks are to be fitted to these drain pipes. It is recommended that the bore of the drain pipes be not less than 19 mm (0·75 in).

Saturated Steam

608 The minimum aggregate area of the orifices through the seatings of the safety valves on each boiler and unfired steam generator is to be found by the following formula:—

$$A = \frac{100\,E}{C\,(P + 1{,}05)}$$

$$\left(A = \frac{E}{C\,(P + 15)} \text{ British}\right)$$

where A = *for ordinary, high lift or improved high lift safety valves*, the aggregate area in mm² (in²) of the orifices through the seatings of the valves, neglecting the area of guides and other obstructions,

= *for full lift safety valves*, the net aggregate area in mm² (in²) through the seats after deducting the area of the guides or other obstructions when the valves are fully lifted,

P = design pressure in kg/cm² (lb/in²) gauge,

E = designed evaporation in kg/hour (lb/hour). In no case is the designed evaporation to be based on less than 29 kg/m² hour (6 lb/ft² hour) of heating surface for coal or oil fired boilers and 14,5 kg/m² hour (3 lb/ft² hour) for exhaust gas heated boilers.

C = 4,8 for valves of ordinary type having a minimum lift of $D/24$,
7,2 for valves of high lift type, having a minimum lift of $D/16$,
9,6 for valves of improved high lift type having a minimum lift of $D/12$,
19,2 for valves of full lift type having a minimum lift of $D/4$,

D = bore of valve seat in mm (in).

When the discharge capacity of a safety valve of approved design has been established by type tests, carried out in the presence of the Surveyors or by an independent authority recognised by the Society, on valves representative of the range of sizes and pressures intended for marine application, consideration will be given to the use of a higher constant than $C = 19,2$ based on 90 per cent of the measured capacity up to a maximum of $C = 45$ for full lift safety valves.

SUPERHEATED STEAM

609 For valves which have to pass superheated steam, the aggregate area of the valves is to be the area A required by 608, multiplied by the factor:—

$$1 + 0{,}0018t$$
$$(1 + 0{\cdot}001t \text{ British})$$

where t = degree of superheat in degC (degF).

Unfired Steam Generators

610 Steam heated steam generators are to be protected from excessive pressure resulting from any failure of the high pressure heating tubes. For this purpose, the area of safety valves obtained by the formula in 608 may require to be increased unless other protective devices are provided to control the supply of steam to the heating tubes.

Waste Steam Pipe

611 For ordinary, high lift and improved high lift type valves, the cross-sectional area of the waste steam pipe and passages leading to it, is to be at least 10 per cent greater than the aggregate area of the safety valves as calculated by the foregoing formulæ. For other valves the cross-sectional area of the waste steam pipe and passages is not to be less than 0,1 C times the aggregate valve area.

The cross-sectional area of the main waste steam pipe is not to be less than the combined cross-sectional areas of the branch waste steam pipes leading thereto from the boiler safety valves.

Waste steam pipes from boilers and unfired steam generators are to be led to the atmosphere and are to be adequately supported and provided with suitable expansion joints, bends or other means to relieve the safety valve chests of undue loading.

The scantlings of waste steam pipes and silencers are to be suitable for the maximum pressure to which the pipes may be subjected in service and not less than 0,25 times the pressure to which the valves are to be set.

Silencers fitted to waste steam pipes are to be so designed that the clear area through the baffle plates is not less than that required for the pipes.

The safety valves of each exhaust gas heated economiser and each exhaust gas heated boiler which may be used as an economiser are to be provided with entirely separate waste steam pipes.

External drains and exhaust steam vents to atmosphere are not to be led to waste steam pipes.

It is recommended that a scale trap and means for cleaning be provided at the base of each waste steam pipe to the Surveyors' satisfaction.

Accumulation Tests

612 All safety valves are to be set under steam to a pressure not greater than 3 per cent above the approved design pressure of the boiler. During a test of 15 minutes with the stop valves closed and under full firing conditions the accumulation of pressure is not to exceed 10 per cent of the design pressure. During this test no more feed water should be supplied than is necessary to maintain a safe working water level.

Stop Valves

613 One main stop valve is to be fitted to each boiler secured direct to the shell. There are to be as few auxiliary stop valves as possible so as to avoid piercing the boiler shell more than is absolutely necessary. The arrangement, however, is to be such that where more than one boiler is fitted it is possible to supply the steam whistle, the steam steering gear, and the electric light machinery from at least two boilers.

Water Level Indicators on Cylindrical Boilers

614 Every boiler is to be fitted with at least two independent means of indicating the water level in it, one of which is to be a glass gauge. The other means is to be either an additional glass gauge or an approved equivalent device.

On double-ended boilers, the above two water level indicators are to be fitted at each end, one indicator being positioned on each side.

On single-ended boilers, the water level indicators are also to be fitted one on each side of the boiler.

615 A set of not less than two test cocks will be accepted as the approved equivalent device mentioned in 614, for boilers having a design pressure less than 8,4 kg/cm^2 (120 lb/in^2) or an internal diameter less than 1,83 m (6 ft).

The test cocks are to be fitted, where practicable direct to the boiler plating.

616 The water gauges are to be readily accessible and placed so that the water level is clearly visible.

The lowest visible part of the glass of the water gauge and the lower test cock, where test cocks are fitted, are to be situated at the lowest safe working water level.

617 The level of the highest part of the effective heating surfaces, e.g., combustion chamber top of a horizontal boiler and the furnace crown of a vertical boiler, is to be clearly marked in a position adjacent to the glass water gauge.

618 The cocks of all water gauges are to be accessible from positions free from danger in the event of the glass breaking.

619 If the water gauges are not fitted directly to the shell of the boiler but to stand pillars or columns, it is desirable that these pillars or columns should be bolted directly to the shell of the boiler. If they are connected to the boiler by means of pipes, the pipes are to be fitted with terminal cocks, not valves, secured direct to the boiler shell. For boilers exceeding 3 m (10 ft) in diameter the pillars are not to be less than 63 mm (2·5 in) and the connecting pipes not less than 38 mm (1·5 in) internal diameter. For boilers exceeding 2,3 m (7 ft 6 in) but not exceeding 3 m (10 ft) in diameter the pillars are not to be less than 50 mm (2 in) and the pipes not less than 32 mm (1·25 in) internal diameter, and for boilers 2,3 m (7 ft 6 in) in diameter and under, the pillars are not to be less than 45 mm (1·75 in) and the pipes not less than 25 mm (1 in) internal diameter. The upper ends of the connecting pipes are to be so arranged that there is no pocket or bend where an accumulation of water from the condensation of the steam can lodge. They should not pass through the uptake if they can be otherwise arranged. If, however, this condition cannot be complied with, they may pass through it by means of a passage at least 50 mm (2 in) clear of the pipe all round, open for ventilation.

Low Water Level Fuel Shut-Off and Alarm

620 Each oil fired boiler is to be fitted with a system of water level detection which is to be independent of any other mounting and which will operate audible and visible alarms and shut off automatically the oil supply to the burners when the water level falls to a predetermined low level.

Feed Check Valves

621 Two feed check valves, connected to separate feed lines, are to be provided for all main and auxiliary boilers which are required for essential services with the exception of boilers in which steam is generated exclusively by exhaust gas or steam, where one feed check valve will be accepted. (*See* E 701).

The feed check valves are to be attached, wherever practicable, direct to the boiler but where the arrangements necessitate the use of standpipes between the boiler and the check valves, these pipes are to be of steel or other approved material.

For boiler feed water systems, *see* E 7

Pressure Gauges

622 Each boiler is to be provided with a separate steam pressure gauge. Double-ended boilers are to be provided with a pressure gauge at each end. The gauges are to be placed where they are easily seen.

Blow-down and Scum Valves

623 Each boiler is to be fitted with at least one blow-down valve secured direct to the lower part of the boiler.

Where it is not practicable to attach the blow-down valve direct to water tube boilers, the valve may be placed immediately outside the boiler casing with a steel pipe of substantial thickness fitted between the boiler and valve. The pipe and valve are to be suitably supported and any pipe which may be exposed to direct heat from the furnace is to be adequately protected.

The blow-down valve and its connections to the sea need not be more than 38 mm (1·5 in) and is not to be less than 19 mm (0·75 in) in diameter. For cylindrical boilers the size of the valve in mm (in) may be generally 0,0085 times the diameter of the boiler in mm (in).

Vertical boilers are to be fitted with a blow-down valve or cock.

624 Blow-down valves and scum valves (where these latter are fitted) of two or more boilers may be connected to one common discharge, but where thus arranged there are to be screw-down non-return valves fitted for each boiler to prevent the possibility of the contents of one boiler passing to another.

For blow-down valve or cock on ship's side and attachments, *see* E 267 to E 270.

Salinometer Valve or Cock

625 Each boiler is to be provided with a salinometer valve or cock secured direct to the boiler in a convenient position. The valve or cock is not to be on the water gauge standpipe.

Hydraulic Test

626 All boiler mountings are to be subjected to a hydraulic test of twice the design pressure with the exception of feed check valves which are to be tested to 2,5 times

the design pressure. The test pressures need not, however, be more than 70 kg/cm^2 (1000 lb/in^2) above the design pressure.

MOUNTINGS AND FITTINGS FOR WATER TUBE BOILERS

General

627 Mountings and fittings not mentioned in 628 to 638 are to be in accordance with the requirements in 601 to 625.

Safety Valves

628 Water tube boilers are to be fitted with not less than two safety valves of area and design in general accordance with the requirements of 605 to 609, except that the minimum diameter of high discharge type valves may be 25 mm (1 in) or equivalent free area.

Each saturated steam drum and each superheater are to be provided with at least one safety valve.

Where the superheater forms an integral part of the boiler the relieving capacity of the superheater safety valve(s), based on the reduced pressure at the superheater outlet, may be included as part of the total relieving capacity required for the boiler. As some National Authorities limit the proportion of the superheater safety valve relieving capacity which may be credited towards the total capacity required for the boiler, builders should give attention to any relevant statutory requirements of the National Authority of the country in which the ship is to be registered.

The boiler and superheater safety valves are to be so disposed and proportioned between saturated steam drum and superheater outlet that the superheater will be protected from overheating under all service conditions, including an emergency stop of the ship at full power.

Where it is proposed to fit full bore safety valves operated by independent pilot valves, the arrangements are to be submitted for consideration. The pipes connecting pilot valves and main valves are to be of ample bore and wall thickness to minimise the possibility of obstruction and damage.

Where it is impracticable to attach safety valves directly to the superheater the valves are to be located as near as possible thereto and fitted to a branch piece connected to the superheater outlet pipe.

In high temperature installations the drains from safety valves are to be led to a tank or other place where high temperature steam can be safely discharged.

Waste Steam Pipe

629 The waste steam pipe and passages leading to it from the safety valves are to be in general accordance with the requirements of 611.

In installations operating with a high degree of superheat, consideration is to be given to the high temperatures which waste steam pipes, silencers and surrounding spaces will attain when the superheater safety valves are blowing during accumulation tests and in service; adequate protection against heat effects is to be provided to the Surveyor's satisfaction. Waste steam pipes are to be led well clear of electric cables and any parts or structures sensitive to heat or likely to distort; the pipes are to be insulated where necessary. In these installations each boiler should have a separate waste steam pipe system to atmosphere with supporting and expansion arrangements such that no direct loading is imposed on the safety valve chests.

Safety Valve Settings

630 All boiler and superheater safety valves are to be set under steam to their respective working pressures which are to be not greater than 3 per cent above the approved design pressure of the boiler. In the setting of superheater safety valves, allowance is to be made for the pressure drop through the superheater so that under discharge conditions the pressure in the boiler will not exceed the approved boiler pressure.

In no case shall the superheater safety valve setting exceed by more than 3 per cent the pressure for which the steam piping and shafting are approved.

Accumulation Tests

631 Tests for accumulation of pressure are to be carried out with the stop valve closed and under full firing conditions for a period not exceeding seven minutes. The accumulation is not to exceed 10 per cent of the design pressure.

Where accumulation tests might endanger the superheaters, consideration will be given in cases of oil-fired boilers to the omission of these tests, provided that application is made when the boiler plan and sizes of safety valves are submitted for approval, and that the safety valves are of an approved type for which the capacity has been established by test in the presence of the Surveyors or an approved independent authority, or for which the Society is satisfied, by long experience of accumulation tests, that the capacity is adequate.

When it is agreed to waive accumulation tests it will be required that the valve makers provide a certificate for each safety valve, stating its rated capacity at the approved

working conditions of the boilers and that the boiler makers provide a certificate for each boiler stating its maximum evaporation.

The safety valves are to be found satisfactory in operation under working conditions during the trials of the machinery on board ship.

Stop Valves

632 Where two or more boilers are connected together, stop valves of self-closing or non-return types are to be fitted.

Water Level Indicators

633 Every boiler is to be fitted with at least two independent means of indicating the water level in it, one of which is to be a glass water gauge.

The other means is to be either an additional glass water gauge or an approved equivalent device other than test cocks, but where a steam and water drum exceeding 3,96 m (13 ft) in length is fitted athwartships, two glass water gauges are to be fitted in suitable positions, one near each end of the drum.

634 The position of the glass water gauges of boilers in which the tubes are entirely drowned when cold is to be such that water is just showing in the glass when the water level in the steam drum is just above the top of the uppermost tubes when the boiler is cold. In boilers, the tubes of which are not entirely drowned when cold, the glass water gauges are to be placed, to the Surveyor's satisfaction, in the positions which have been found by experience to indicate satisfactorily that the water content is sufficient for safety when the boiler is worked under all service conditions.

Low Water Level Fuel Shut-Off and Alarm

635 Each oil fired boiler is to be fitted with two systems of water level detection which are to be independent of each other and of any other mounting on the boiler. Both systems are to operate audible and visible alarms and shut off automatically the oil supply to the burners when the water level falls to a predetermined low level.

Any proposal to depart from these requirements in the case of small auxiliary boilers would be the subject of special consideration.

Feed Check Valves and Water Level Regulators

636 Two feed check valves, connected to separate feed lines, are to be provided for each boiler and are to be attached, wherever practicable, direct to the boiler or to an economiser which forms an integral part of the boiler.

Where, however, the arrangements necessitate the use of a common inlet pipe on the economiser for both main and auxiliary feed systems, this pipe is to be as short as practicable and the arrangement of check valves is to be such that either feed line can be effectively isolated without interruption of the feed water supply to the boiler.

At least one of the feed water systems is to be fitted with an approved feed water regulator whereby the water level in the boilers is controlled automatically. (*See* E 7 for arrangements and details of boiler feed systems.)

637 The feed check valves are to be fitted with efficient gearing, whereby they can be satisfactorily worked from the stokehold floor, or other convenient position.

638 Standpipes on boilers, for feed inlets, are to be designed with an internal pipe to prevent direct contact between the feed pipe and the boiler shell or end plates with the object of minimizing thermal stresses in these plates.

Similar arrangements are to be provided for desuperheater and other connections where significant temperature differences occur in service.

Hydraulic Tests

639 All boiler mountings are to be subjected to a hydraulic test of twice the approved boiler design pressure with the exception of feed check valves and other mountings connected to the main feed system which are to be tested to 2,5 times the approved boiler design pressure, or twice the maximum pressure which can be developed in the feed line in normal service, whichever is the greater.

MOUNTINGS AND FITTINGS FOR UNFIRED PRESSURE VESSELS

General

640 Each receiver which can be isolated from a safety valve is to be provided with a suitable fusible plug to discharge the contents in case of fire. The melting point of the fusible plug is to be approximately 150°C (300°F). (*See also* F 310).

Where carbon dioxide gas is used for fire extinguishing, it is recommended that the discharge from the fusible plug be piped to deck.

641 Each receiver is to be fitted with a drain arrangement at its lowest part, permitting oil and water to be blown out.

Cross-references

642 For starting air pipe systems and safety fittings, *see* H 612.

For mountings for liquefied petroleum gas vessels, *see* E 12.

Section 7

PRESSURE VESSELS FOR THE CARRIAGE OF LIQUEFIED PETROLEUM GASES

General

701 The requirements of this Section are applicable to welded steel pressure vessels of cylindrical or spherical form intended for the carriage of liquefied petroleum gas under pressure at ambient or lower temperatures. The vessels should be constructed generally in accordance with the Rules for Welded Pressure Vessels Class 1 and installed in closed holds with the vessels and their mountings protruding above the weather deck (*see* 704).

See E 12 for requirements for filling, discharging, venting and inerting pipe arrangements, tank connections and mountings, cargo pumps and compressors and other associated equipment.

See D 70, D 71 and D 72 for ship requirements for the carriage of liquefied gases.

Plans

702 Before construction of the vessels is commenced the following particulars where applicable and plans are to be submitted for approval:—

(1) Nature of cargoes, together with maximum vapour pressure and minimum liquid temperature for which the pressure vessels are to be approved, and proposed hydraulic test pressure.

(2) Particulars of materials proposed for the construction of the vessels (*see* 703).

(3) Particulars of refrigeration equipment.

(4) General arrangement plan showing location of pressure vessels in the ship.

(5) Plans of pressure vessels showing attachments, openings, dimensions, details of welded joints and particulars of proposed stress relief heat treatment.

(6) Plans of seatings, securing arrangements and deck sealing arrangements.

(7) Plans showing arrangement of mountings, level gauges and number, type and size of safety valves.

Materials

703 Plate materials are to be manufactured and tested in accordance with the requirements of Q 3 and the specification of the material is to be submitted for approval as required by Q 301 for steels operating at low metal temperatures. In addition to the tensile and bend test requirements the tests of plates at the steel works are to include Charpy V-notch impact tests at the design metal temperature.

For pressure vessels where the carrying temperature is 0°C (32°F) or less, specifications of the weld metal as well as the plate material, including Charpy V-notch impact properties at the carrying temperatures, are to be submitted for approval. For pressure vessels where the cargo is carried at atmospheric temperature the plate material is to have minimum impact properties of 4,84 kg m (35 ft lb) at 0°C (32°F). For details of impact tests *see* Q 208. Tests to determine the impact strength of the weld metal should have regard to variations in welding positions.

Design

704 For pressure vessels where the cargo is carried at atmospheric temperature, the vapour pressure used for design purposes is not to be less than the vapour pressure of liquefied gas at 45°C (113°F).

The thickness at any part of the pressure vessel is not to be less than determined by the formula in J 201, J 208 and J 209, as applicable, for a design pressure appropriate to the vapour pressure and static liquid head. The thickness so obtained is to be increased where necessary to take account of the following:—

(*a*) local stresses in shell and ends due to reactions from seatings and securing fitments when the ship is upright or listed up to 30°,

(*b*) thermal expansion and contraction effects where the liquid cargo is to be carried at temperatures below ambient,

(*c*) dynamic loading from rolling, pitching and heaving of the ship in a seaway to the extent given in D 7116. Alternatively, provision for dynamic loading can be made by assuming that pressures due to static head are doubled.

Special attention is to be given to the design of attachments welded to the pressure vessel for supporting or securing purposes so as to minimise stress concentrations at these points.

Seatings are to be so designed as to ensure adequate and uniform support to the pressure vessel having due regard to deflections of the hull structure in a seaway.

All valves, fittings and manholes are to be located on that portion of the pressure vessel which protrudes above the weather deck, and are to be protected from damage and corrosion. Manholes should be placed above the liquid level. Valves and fittings are to be of steel or other approved ductile material.

The sealing arrangements at deck are to provide for expansion and contraction of the vessel under normal operating pressure and temperature and are to be watertight.

Suitable arrangements are to be made to prevent the pressure, temperature and liquid level of tanks from rising above safe limits, and details are to be submitted. It should also be stated whether the safety arrangements are controlled by statutory requirements of any National Authority.

Refrigeration Equipment

705 Where refrigeration equipment is installed, two or more refrigerating units are to be provided of capacity sufficient to maintain the liquid cargo at the carrying temperature with any one unit out of use. (*See* E 1228).

Construction and Tests

706 In general, pressure vessels are, so far as practicable, to be constructed and tested to the Rules for Class 1 Welded Pressure Vessels, except that the work may be carried out by manufacturers not appearing on the Society's Class 1 List, provided fabrication and tests are completed to the satisfaction of the Surveyors.

Some relaxation of Class 1 requirements as regards tests and heat treatment may be permitted, dependent on design, scantlings and material of the vessel, but generally, welded joints should be subjected to radiographic examination. Where the pressure vessels are too large for furnace stress relief, proposals for local stress relief and stress relief of prefabricated components will be considered.

Where plates are hot formed to shape, check tests including impact tests are to be made on the material. Where a large number of plates are involved, check tests on selected plates will suffice, provided the Surveyor is satisfied that the hot forming process is closely controlled.

For pressure vessels where the operating metal temperature is 0°C (32°F) or less, the weld metal Charpy V-notch impact test specimens are to be prepared as stated in J 419. The impact tests are to be made at the carrying temperature for which the vessel is approved and the test results are to comply with approved specification. (*See* 703).

Hydraulic Tests

707 The pressure vessel is to be tested as required by J 445. The static head of the water may be included in the test pressure if the amount is significant.

On completion, the vessels are to be clearly marked with the maximum vapour pressure and minimum carrying temperature.

Section 8

RIVETED PRESSURE VESSELS

NOTE.—The use of fusion welded construction has almost entirely replaced riveted construction for new fired and unfired pressure vessels. Similarly, the staying of flat surfaces by welded attachment of the stays has to a great extent replaced screwed, nutted and riveted forms of stay attachment. Nevertheless, in the event of riveted construction and screwed, nutted and riveted forms of stay attachments being used for new pressure vessels or in the repair of existing pressure vessels, the following Rules are applicable. These Rules, though presented in a different form, embody the requirements of the Society's previous Rules for riveted pressure vessels.

General

801 All steel plates which are welded, dished, flanged or locally heated are to be afterwards efficiently heat treated.

802 Butt straps are to be cut from plates and not from rolled strips.

803 All rivet holes are to be drilled, and as far as possible they are to be drilled in place. After drilling the plate the burrs are to be removed and the faying surfaces of the plates cleaned, and the sharp outer edges of holes also removed.

804 Steel stays are not to be welded. If plus threads are desired, the ends of the stay bars may be upset or the bars may be drawn down in the central portions from bars originally of the size of the ends. In either of these two cases the bars are to be subsequently annealed throughout. In double-ended boilers the through longitudinal stays are to be supported at or near the middle of their length.

805 Screw stays of combustion chambers where fitted with nuts are to be, as far as possible, normal to the chamber plates. Where this is not possible they are to be fitted with taper washers to provide a fair bed for the nuts.

806 Nuts to screw stays in combustion chambers are not to be less than 19 mm (0·75 in) thick for stays up to 38 mm (1·5 in) diameter over threads, 22 mm (0·875 in) thick for 41 and 45 mm (1·625 and 1·75 in) stays, 25 mm (1 in) thick for 48 and 51 mm (1·875 and 2 in) stays, and 29 mm (1·125 in) thick for stays over 51 mm (2 in) in diameter. The nuts are to be made of solid mild steel or of iron which is to be without weld. The nuts for longitudinal stays are to be appropriate to the diameters of the stays, the outside nuts having the thickness provided for ordinary nuts, and the inside nuts having the thickness provided for lock nuts.

807 Screw stays 32 mm (1·25 in) in diameter and above should have 9 threads per 25,4 mm (1 in), and all stays 51 mm (2 in) in diameter and above passing through plates, and secured by nuts on each side of the plate, should have not more than 6 threads per 25,4 mm (1 in).

808 Where jointed longitudinal stays are fitted between the front and back tube plates they are to be fitted with pins having an effective sectional area not less than 25 per cent in excess of that of the stay. The pins may be slack in the holes, the total slackness being not more than 1,5 mm (0·0625 in). The pins are to be as close as possible to the shoulder of the eye forging. The shoulder of the forging is to have a diameter not less than 25 mm (1 in) greater than the diameter of the hole.

809 The end plates in the steam space in way of uptakes are to be shielded from contact with the heated gases.

Cross-reference

810 For requirements as to smoke box doors and the omission of dampers in oil-fired boilers, *see* E 332 and E 333.

CYLINDRICAL SHELLS SUBJECT TO INTERNAL PRESSURE

Minimum Thickness

811 The minimum thickness, T, of a cylindrical shell is to be determined by the following formula:—

$$T = \frac{PD}{52{,}2\, R_{20}\, J} + 1{,}6 \text{ mm}$$

$$\left(T = \frac{PD}{1162\, R_{20}\, J} + 0{\cdot}06 \text{ in}\right)$$

where T is as stated above, in mm (in),

P = design pressure, in kg/cm² (lb/in²)

R_{20} = specified minimum tensile strength of plate, in kg/mm² (ton/in²),

J = strength of the longitudinal seams, with double butt straps, calculated by the methods described in 812—expressed as a fraction,

D = inside diameter of the outer strake of plating of the cylindrical shell, in mm (in).

Joint Strength

812 The strength of a riveted joint, J, is found from the following formulæ, the first two being applicable to any type of joint, and the third to that type of joint in which the number of rivets in the inner rows is double that in the outer row. The lowest value given by the application of these formulæ is to be taken as the strength of the joint.

Strength of plate at joint as compared with solid plate $\left.\right\} = \dfrac{p - d}{p}$ (1)

Strength of rivets as compared with solid plate $\left.\right\} = \dfrac{S\,a\,n\,C}{R_{20}\, p\, T}$ (2)

Combined strength of the plate at the inner row of rivet holes and of the rivets in the outer row

$$= \frac{p - 2d}{p} + \frac{S\,a\,C}{R_{20}\, p\, T} \quad (3)$$

where p = pitch of rivets at outer rows, in mm (in),

d = diameter of rivet holes, in mm (in),

a = sectional area of one rivet, in mm² (in²),

n = number of rivets which are fitted in the pitch p,

T = thickness of plate, in mm (in),

R_{20} = specified minimum tensile strength of plates, in kg/mm² (ton/in²),

S = shearing strength of rivets, which is taken generally to be 36 kg/mm² (23 ton/in²), and may be 0,85 of the minimum tensile strength of the rivet bars,

C = 1,0 for rivets in single shear as in lap circumferential joints, 1,875 for rivets in double shear as in double butt-strapped longitudinal joints.

813 All longitudinal seams are to be butt jointed with double butt straps; the outer butt strap is to be at least 0,625 of the strength of the plate and of sufficient thickness to permit of efficient caulking at its outer edges. The inner butt strap is to be 3 mm (0·125 in) thicker than the outer butt strap.

In cases where the number of rivets in the inner rows is double the number in the outer row, the minimum thickness of the outer butt strap T_o, in mm (in) is to be:—

$$T_o = \frac{0{,}625\,(p - d)\,T}{(p - 2d)} \quad (1)$$

and the minimum thickness of the inner strap T_i, in mm (in), is to be:—

$$T_i = \frac{0{,}625\,(p - d)\,T}{(p - 2d)} + 3 \text{ mm} \quad (2)$$

$$\left(T_i = \frac{0{\cdot}625\,(p - d)\,T}{(p - 2d)} + 0{\cdot}125 \text{ in}\right)$$

Spacing of Rivets

814 In all cases the clear space between a rivet hole and the edge of a plate is not to be less than the diameter of the rivet holes, i.e., the centre of the rivet hole is to be at least 1,5 diameters from the edge of the plate.

In joints whether lapped or fitted with butt straps, in which there are more than one row of rivets and in which there is an equal number of rivets in each row, the distance between the rows of rivets is not to be less than $0{,}33\ p + 0{,}67\ d$ with zigzag riveting, or $2d$ with chain riveting.

In joints in which the number of rivets in the outer rows is one-half of the number in each of the inner rows, and in which the inner rows are chain riveted, the distance between the outer rows and the next rows is not to be less than $0{,}33\ p + 0{,}67\ d$ or $2d$, whichever is the greater, and the distance between the rows in which there are the full number of rivets is not to be less than $2d$.

In joints in which the number of rivets in the outer rows is one-half of the number in each of the inner rows and in which the inner rows are zigzag, the distance between the outer rows and the next rows is not to be less than $0{,}2\ p + 1{,}15\ d$, and the distance between the rows in which there are the full number of rivets is not to be less than $0{,}165\ p + 0{,}67\ d$.

In the above, p is the pitch of the rivets in the outer rows.

815 In longitudinal seams, with double butt straps, the maximum pitch of the rivets is not to be greater than:—

$$C\,T + 40\text{ mm} \qquad (C\,T + 1{\cdot}625\text{ in})$$

where T is the thickness of the plate, in mm (in), and C is a coefficient as given in Table J 8.1.

TABLE J 8.1

Number of Rivets per Pitch	Coefficient C
1	1,75
2	3,50
3	4,63
4	5,52
5	6,00

Circumferential Seams

816 The strength of the seams joining the end plates to the cylindrical shell is not to be less than 0,42 of that of the solid shell plate. Where the shell plates exceed 16 mm (0·625 in) in thickness the seams connecting the shell plates to the end plates are to be at least double riveted. Where the shell plates exceed 13 mm (0·5 in) in thickness the intermediate circumferential seams of double-ended boilers are to be at least double riveted.

817 The circumferential seam at or near the middle of the length of single-ended boilers is to have a strength of joint not less than 0,6 of the solid plate. The inner circumferential seams of double-ended boilers are to have a strength of joint not less than 0,62 of the solid plate. In any case there are to be at least three rows of rivets where single-ended boilers have shell plates over 35 mm (1·375 in) in thickness and where double-ended boilers have shell plates over 30 mm (1·187 5 in) in thickness.

818 The circumferential seams of the shells of vertical boilers are to have a strength of not less than 0,42 of the solid plate. Where these seams are not complete circles, and where the shell plates exceed 16 mm (0·625 in) in thickness, the riveting is to be at least double.

Strength of Cylindrical Shells in way of Stays and Openings

819 Where more than three screw stays pierce the cylindrical shell in a horizontal line, if d is their diameter and p the pitch, $\frac{p-d}{p}$ should be not less than the strength required for the shell longitudinal joints. To meet this requirement it may be necessary for the stays to be arranged out of line with one another longitudinally.

820 If holes are cut in cylindrical shells for manholes, sight holes or for fixing of mountings, the diameters of the holes being greater than 2,5 times the thickness of the shell plating plus 70 mm (2·75 in), compensation is to be provided such that the strength in way of the holes is not less than that required for the longitudinal joint.

HEMISPHERICAL ENDS SUBJECT TO INTERNAL PRESSURE

Minimum Thickness

821 The minimum thickness, T, of a hemispherical end without stays or other supports and made from more than one plate is to be determined by the following formula:—

$$T = \frac{P\,R_i}{C\,R_{20}\,J} + 1{,}6\text{ mm} \quad \left(T = \frac{P\,R_i}{C\,R_{20}\,J} + 0{\cdot}06\text{ in}\right)$$

where T is as stated above, in mm (in),

P = design pressure, in kg/cm^2 (lb/in^2),

R_{20} = specified minimum tensile strength of plate, in kg/mm^2 (ton/in^2),

J = strength of riveted joint as a fraction of the solid plate,

R_i = inner radius of curvature, in mm (in),

C = 50,6 (1130) for treble riveted,
49,4 (1100) for double riveted,
43,3 (970) for single riveted.

FLAT PLATES SUPPORTED BY STAYS SECURED IN VARIOUS WAYS OTHER THAN WELDING

NOTE.—*If steel of a tensile strength less than* 41 *kg/mm*^{2} (26 *ton/in*^{2}) *is used for flat plates, then the design pressure calculated by the following formulæ for a given plate thickness would require to be correspondingly reduced.*

Minimum Thickness

822 The minimum thickness, T, of flat plates supported by stays is to be determined by the following formula:—

$$T = d\sqrt{\frac{P}{C}} + 0{,}8\text{ mm} \quad \left(T = d\sqrt{\frac{P}{C}} + 0{\cdot}031\,25\text{ in}\right) \qquad (1)$$

In this formula and in the formulæ in 824

T is as stated above, in mm (in),

P = design pressure, in kg/cm^2 (lb/in^2),

T_W = thickness, in mm (in), of the washers, strips, or doublings employed,

d = $\sqrt{A^2 + B^2}$ where the stays are regularly pitched,

A being the horizontal pitch of the stays, in mm (in), and

B the vertical pitch of the stays, in mm (in).

Where the stays are irregularly pitched, then

d = diameter of the largest circle which can be drawn through three points of support without enclosing another point of support. Only two points of support may be on one side of any diameter of the circle. Where a flange is taken as a point of support, the circumference of the circle is to be tangent to the line of curvature,

C = a constant, depending on the method of support as detailed below. Where various forms of support are used the constant C is to be the mean of the values for the respective methods adopted.

Where stays are screwed into the plate and their ends are riveted over, then:—

for plates not exposed to flame C = 4100 (C = 58 350),
for plates exposed to flame C = 3600 (C = 51 200).

In these cases the thickness of the plate is to be at least half the diameter of the stay required by the Rules.

Where stays are screwed into the plate and fitted with nuts on the outside, then:—

for plates not exposed to flame C = 6200 (C = 88 050).
for plates exposed to flame C = 5400 (C = 76 800).

Where stays pass through the plate and are fitted with nuts inside and outside, then:—

for plates not exposed to flame C = 6900 (C = 98 300),
for plates exposed to flame C = 6050 (C = 86 000).

Where plates are stiffened by flanging, the outer radius of which is not greater than 3,5 times the thickness of the plate, then:—

for plates not exposed to flame C = 7900 (C = 112 800),
for plates exposed to flame C = 6900 (C = 98 300).

Where stay tubes are screwed into tube plates, and expanded, then:—

for stay tubes fitted with nuts C = 5180 (C = 73 700),
for stay tubes not fitted with nuts C = 3740 (C = 53 250).

Where a flat plate has a manhole or sight hole and the opening is strengthened by flanging, the total depth, H, of the flange, measured from the outer surface of the plate is not to be less than:—

$$H = \sqrt{T\,W} \qquad (2)$$

where H = depth of flange, in mm (in),

T = thickness of the plate, in mm (in),

W = minor axis of the manhole or sight hole, in mm (in).

823 For the tops and sides of combustion chambers the distance between the rows of stays nearest to the back tube plate or the back plate respectively and the commencement of curvature of these plates at their flanges is not to be greater than the distance apart of the rows of stays, in mm (in).

The stays of the combustion chambers are to be so placed that the seams of the plates can be caulked without removing the stay nuts.

For the tops of combustion chambers where they are joined to the sides by curved portions, if the outer radius of the curved portion is less than half the allowable distance between the girders, the distance between the first girder and the inner surface of the side plate is not to exceed the allowable distance between the girders. If the radius of the curved portion is greater than half the allowable distance between the girders, the width of the flat portion measured from the centre of the girder is not to be more than half the allowable distance between the girders.

824 Where the plate is strengthened by washers, stiffening strips or doubling plates having a thickness, T_W, at least two-thirds of that of the plate but not greater than that of the plate, then the minimum thickness, T, of the plate is to be determined as follows:—

(*a*) Where stays pass through the plate and are fitted with nuts inside and washers and nuts outside, the diameter of the washers being at least 3,5 times that of the stay,

$$T = \sqrt{\frac{P\,d^2}{7200} - 0{,}15\,T_W^2} + 0{,}8 \text{ mm} \qquad (1)$$

$$\left(T = \sqrt{\frac{P\,d^2}{102\,400} - 0{\cdot}15\,T_W^2} + 0{\cdot}031\,25 \text{ in}\right)$$

(*b*) Where the stays, nuts and washers are fitted as in (*a*), the diameter of the washers being at least two-thirds of the pitch of the stays and riveted to the plate in an efficient manner,

$$T = \sqrt{\frac{P\,d^2}{7200} - 0{,}35\,T_W^2} + 0{,}8 \text{ mm} \qquad (2)$$

$$\left(T = \sqrt{\frac{P\,d^2}{102\,400} - 0{\cdot}35\,T_W^2} + 0{\cdot}031\,25 \text{ in}\right)$$

(*c*) Where the plate is stiffened by strips at least two-thirds of the pitch of the stays in breadth and riveted to the plate in an efficient manner,

$$T = \sqrt{\frac{P\,d^2}{7200} - 0{,}55\,T_W^2} + 0{,}8 \text{ mm} \qquad (3)$$

$$\left(T = \sqrt{\frac{P\,d^2}{102\,400} - 0{\cdot}55\,T_W^2} + 0{\cdot}031\,25 \text{ in}\right)$$

(*d*) Where the plate is fitted with doubling plates which are riveted to the plate in an efficient manner,

$$T = \sqrt{\frac{P\,d^2}{7200} - 0{,}85\,T_W^2} + 0{,}8 \text{ mm} \qquad (4)$$

$$\left(T = \sqrt{\frac{P\,d^2}{102\,400} - 0{\cdot}85\,T_W^2} + 0{\cdot}031\,25 \text{ in}\right)$$

825 (*a*) For the portions of tube plates in the nests of tubes the minimum thickness, T, of the tube plate is to be determined as follows:—

$$T = p_m\sqrt{\frac{P}{C}} + 0{,}8 \text{ mm} \qquad (1)$$

$$\left(T = p_m\sqrt{\frac{P}{C}} + 0{\cdot}031\,25 \text{ in}\right)$$

where T is as stated above, in mm (in),

P = design pressure, in kg/cm² (lb/in²),

p_m = mean pitch, in mm (in), of the stay tubes supporting any portions of the plate (being the sum of the four sides of the quadrilateral divided by 4),

C = 3530 (C = 50 200) where the stay tubes are screwed and expanded into the plate and nuts are fitted (*see* J 250),

C = 2740 (C = 38 900) where the stay tubes are screwed and expanded into the plate and nuts are not fitted.

(*b*) For the wide water spaces of front tube plates between the nests of tubes and between the wing rows of tubes and the shell the minimum thickness, T, of the front tube plate is to be determined as follows:—

$$T = \sqrt{\frac{P\,d^2}{C} - 0{,}55\,T_W^2} + 0{,}8 \text{ mm} \qquad (2)$$

$$\left(T = \sqrt{\frac{P\,d^2}{C} - 0{\cdot}55\,T_W^2} + 0{\cdot}031\,25 \text{ in}\right)$$

where T is as stated above, in mm (in),

P = design pressure, in kg/cm² (lb/in²),

T_W = thickness of the doubling plate, where so fitted, in mm (in),

$d^2 = A^2 + B^2$,

A = horizontal pitch of stay tubes, in mm (in), measured across the wide water space,

B = vertical pitch of stay tubes in the bounding rows, in mm (in),

C = 5180 (C = 73 700) where the stay tubes are screwed and expanded into the tube plate and nuts are fitted to each stay tube,

C = 4540 (C = 64 500) where the stay tubes are screwed and expanded into the tube plate and nuts are fitted only to alternate stay tubes,

C = 3740 (C = 53 250) where the stay tubes are screwed and expanded into the tube plate and nuts are not fitted.

Combustion Chamber Girders

826 For plate girders supporting the tops of combustion chambers by means of stays, the following formula is to be used:—

$$T = \frac{P\,D\,L\,(L-p)}{C\,d^2}\,\frac{44}{R_{20}} \qquad \left(T = \frac{P\,D\,L\,(L-p)}{C\,d^2}\,\frac{28}{R_{20}}\right)$$

where T = thickness of girder at centre, or the sum of the thicknesses of the plates where the girder is made of two plates, in mm (in),

P = design pressure, in kg/cm^2 (lb/in^2),

d = depth of girder at centre, in mm (in),

L = length of girder, in mm (in), measured between the tube plate and back chamber plate inside, or between tube plates in chambers common to two opposite furnaces,

p = pitch of stays supported by the girder, in mm (in),

D = distance apart of the girders, centre to centre, in mm (in),

R_{20} = minimum specified tensile strength of the material forming the girder, in kg/mm^2 (lb/in^2),

$$\left.\begin{aligned} C &= \frac{n}{n+1}\,1100 \\ \left(C \right.&= \left.\frac{n}{n+1}\,15\,840\right) \end{aligned}\right\}$$ where the number of stays n in each girder is odd,

$$\left.\begin{aligned} C &= \frac{n+1}{n+2}\,1100 \\ \left(C \right.&= \left.\frac{n+1}{n+2}\,15\,840\right) \end{aligned}\right\}$$ where the number of stays n in each girder is even.

23rd July, 1970

Hydraulic Test

827 In all new boilers having design pressures up to 7 kg/cm^2 (100 lb/in^2) the hydraulic test pressure is to be twice the design pressure. For boilers with design pressures greater than 7 kg/cm^2 (100 lb/in^2) the hydraulic test pressure is to be 1,5 times the design pressure plus 3,5 kg/cm^2 (50 lb/in^2).

In air receivers having design pressures up to 21 kg/cm^2 (300 lb/in^2) the hydraulic test pressure is to be 1,5 times the design pressure, plus 3,5 kg/cm^2 (50 lb/in^2). Where higher design pressures are used, the test pressure need not be more than 14 kg/cm^2 (200 lb/in^2) above the design pressure.

Cross-references

828 The design of pressure parts, not mentioned in this Section, is to be in accordance with J 2 where applicable.

Access arrangements are to be in accordance with J 301 to J 307 where applicable.

APPENDIX

Firms recognised by the Committee for the Manufacture of Class 1 Fusion Welded Pressure Vessels

Note: The Society's Office giving attendance at the Works is shown in brackets.

United Kingdom

Adamson & Hatchett, Ltd., Dukinfield, Cheshire. (MANCHESTER)

Adamson, Joseph & Co., Ltd., Hyde, Cheshire. (MANCHESTER)

Aiton & Co., Ltd., Derby. (NOTTINGHAM)

Babcock & Wilcox (Operations), Ltd., Renfrew. (GLASGOW)

Balfour, Henry & Co., Ltd., Leven, Fife. (LEITH)

Brown, John, Engineering (Clydebank) Ltd., Clydebank. (GLASGOW)

Butterfield, W. P. (Engineers) Ltd., P.O. Box No. 38, Shipley, Yorks. (LEEDS)

Cammell Laird & Co. (Shipbuilders & Engineers) Ltd., Birkenhead. (LIVERPOOL)

Clark, George, & N.E.M., Ltd., Hartlepool Works. (MIDDLESBROUGH)

Clarke, Chapman & Co., Ltd., Gateshead. (NEWCASTLE)

Clayton, Son & Co., Ltd., Pepper Road Works and Moor End Works, Hunslet, Leeds. (LEEDS)

Cochran & Co., Annan, Ltd., Annan. (GLASGOW)

Danks, Edwin & Co. (Oldbury) Ltd., (BIRMINGHAM)

Danks of Netherton, Ltd., Netherton. (BIRMINGHAM)

Distington Engineering Co., Workington, Cumberland. (BARROW)

English Electric Co., Ltd., Netherton Works, Netherton, Lancs. (LIVERPOOL)

English Electric Co., Ltd., Stafford. (BIRMINGHAM)

Foster, Yates & Thom, Ltd., Canal Works, Blackburn. (MANCHESTER)

Grazebrook, M. & W., Ltd., Dudley, Worcestershire. (BIRMINGHAM)

Harland & Wolff, Ltd., Belfast. (BELFAST)

Head Wrightson Teesdale, Ltd., Thornaby-on-Tees. (MIDDLESBROUGH)

Hoval-Farrar Boilers, Ltd., Newark. (NOTTINGHAM)

International Combustion, Ltd., Derby. (NOTTINGHAM)

Jenkins, Robert & Co., Ltd., Rotherham. (SHEFFIELD)

Marshall & Anderson, Ltd., Manse Road, Motherwell. (Broomside Works). (GLASGOW)

Marshall, Sons & Co., Ltd., Britannia Works, Gainsborough. (SHEFFIELD)

Millspaugh, Ltd., Sheffield. (SHEFFIELD)

Motherwell Bridge Engineering, Ltd., Motherwell. (GLASGOW)

Neill, Wm., & Son (St. Helens), Ltd., Bold, St. Helens. (LIVERPOOL)

Newton Chambers Engineering, Ltd., Thorncliffe, Nr. Sheffield. (SHEFFIELD)

Old Park Engineering Co., Ltd., Dudley, Worcestershire. (BIRMINGHAM)

Penman & Co., Ltd., Glasgow. (GLASGOW)

Redheugh Iron & Steel Co., Ltd., Teams, Gateshead, Co. Durham. (NEWCASTLE)

Robey of Lincoln, Ltd., Globe Works, Lincoln. (NOTTINGHAM)

Stephen, Alexander, Engineering, Ltd., Glasgow. (GLASGOW)

Thompson, John, Cochran Ltd., P.O. Box 33, Lincoln. (NOTTINGHAM)

Thompson, John, Horseley Bridge, Ltd., Ettingshall, Wolverhampton. (BIRMINGHAM)

Thompson, John, Horseley Bridge, Ltd., Horseley Works, Tipton, Staffs. (BIRMINGHAM)

Thompson, John, Horseley Bridge, Ltd., Windmill Works, Dudley. (BIRMINGHAM)

Towler & Son, Ltd., London, E.15. (LONDON)

Vickers Ltd., Barrow Engineering Works, Barrow-in-Furness. (BARROW)

Watson, Robert & Co. (Constructional Engineers) Ltd., Bolton, Lancs. (MANCHESTER)

Weir, G. & J., Ltd., Cathcart, Glasgow. (GLASGOW)

Whessoe, Ltd., Darlington. (MIDDLESBROUGH)

Whessoe (Stockton Works), Ltd., Stockton-on-Tees. (MIDDLESBROUGH)

Yarrow & Co., Ltd., Scotstoun, Glasgow. (GLASGOW)

Australia

Babcock & Wilcox Australia, Ltd., Regents Park, N.S.W. (SYDNEY)

Bernard-Smith P.D.M. P/L, Sydney. (SYDNEY)

Industrial Engineering, Ltd., Steelweld Fabrications Division, Braybrook, Victoria. (MELBOURNE)

Perry Engineering Co., Ltd., Adelaide, S. Australia. (ADELAIDE)

Thompsons (Castlemaine), Ltd., Melbourne, Victoria. (MELBOURNE)

Vickers Hoskins Pty., Ltd., Bassendean, Western Australia. (FREMANTLE)

Austria

Vereinigte Osterreichische Eisen-und-Stahlwerke AG., Linz an der Donau. (VIENNA)

Waagner-Biro AG., Graz, Styria. (VIENNA)

Belgium

S.A. Cockerill-Ougree-Providence, Seraing. (ANTWERP)

Brazil

Cia. Brasileira de Caldeiras (CBC), Varginha, Minas Gerais. (SAO PAULO)

Canada

Babcock & Wilcox Canada, Ltd., Galt, Ontario. (TORONTO)

Canadian Vickers Industries, Ltd., Montreal. (MONTREAL)

Davie Shipbuilding, Ltd., Lauzon, P.Q. (QUEBEC)

Dominion Bridge Co., Ltd., Lachine, P.Q. (QUEBEC)

Foster Wheeler, Ltd., St. Catherines, Ontario. (TORONTO)

Denmark

Aalborg Vaerft A/S, Aalborg. (AALBORG)

Burmeister & Wain A/S, Copenhagen. (COPENHAGEN)

Finland

Valmet Oy, Rautpohjan tehdas, Jyvaskyla. (HELSINGFORS)

Oy Wärtsilä A/B, Helsinki Works, Helsingfors. (HELSINGFORS)

France

Ateliers & Chantiers de Bretagne, Nantes. (NANTES)

Babcock Atlantique, St. Nazaire. (NANTES)

Compagnie de Fives-Lille-Cail, Usine de Fives in Fives-Lille, Nord. (VALENCIENNES)

Germany

Deutsche Babcock & Wilcox Dampfkesselwerke A.G., Oberhausen. (DUSSELDORF)

Borsig A.G., Berlin-Tegel. (BERLIN)

Bremer-Vulkan, Schiffbau & Maschinenfabrik, Bremen-Vegesack. (BREMEN)

Dinglewerke A.G., Zweibruecken, Werke in Zweibruecken und Bierbach-Saar. (SAARBRUCKEN-SAAR)

Gutehoffnungshutte Sterkrade A.G., Werk Sterkrade, Oberhausen-Sterkrade. (DUSSELDORF)

Howaldtswerke-Deutsche Werft A.G., Hamburg und Kiel, Hamburg Werke-Finkenwerder. (HAMBURG)

Howaldtswerke-Deutsche Werft A.G., Hamburg und Kiel, Werk Kiel. (KIEL)

Klockner-Werke A.G., Georgsmarienwerke, Osnabruck Werke Georgsmarienhutte. (HANNOVER)

Koerver & Lersch, Krefeld. (DUSSELDORF)

Krupp, Fried., Industriebau und Maschinenfabrieken Essen Apparatebau, Essen. (DUSSELDORF)

Mannesmann A.G. Rohr-und Bodenwerk Huckingen, Duisburg-Huckingen. (DUSSELDORF)

Maschinenfabrik Augsburg-Nurnberg A.G., Augsburg. (AUGSBURG)

Maschinenfabrik Augsburg-Nurnberg A.G., Gustavsburg. (MANNHEIM)

Maschinenfabrik Augsburg-Nurnberg A.G., Werk Hamburg, Hachmannkai, Hamburg. (HAMBURG)

Rheinstahl Transporttechnik Formteile Ruhrstahl Brackwede, of Brackwede (Westf.) (HANNOVER)

Rheinstahl Hüttenwerke A.G., Werk Ruhrstahl Henrichshuette, Hattingen-Ruhr. (DORTMUND)

Siller & Jamart, Wuppertal Barmen. (DUSSELDORF)

Stahl-und-Rohrenwerke Reischolz G.m.b.H., Dusseldorf-Reisholz. (DUSSELDORF)

Steinmuller, L. & C., G.m.b.H., Gummersbach/Rhld. (HAMBURG)

Thyssen Rohrenwerke A.G., Works Mülheim. (DUSSELDORF)

Weser A.G., Bremen. (BREMEN)

Holland

"Breda" N.V. Machinefabrik, v/h Backer & Rueb, Rotterdam. (ROTTERDAM)
Bronswerk-Feyenoord Afd. AMAF N.V. (AMSTERDAM)
Dok-en Werf-Maatschappij Wilton-Fijenoord N.V., Schiedam. (ROTTERDAM)
Kon. Mij. "De Schelde" N.V., Vlissingen. (ROTTERDAM)
Nederlandsche Dok en Scheepsbouw Mij. (AMSTERDAM)
Nederlandsche Electrolasch Mij. N.V., Leiden. (ROTTERDAM)
Rotterdamsche Droogdok Maatschappij N.V., Rotterdam. (ROTTERDAM)
Stork, Gebr. & Co., N.V., Hengelo. (AMSTERDAM)
Werkspoor Utrecht N.V., Utrecht. (AMSTERDAM)

India

ACC-Vickers-Babcock, Ltd., Durgapur. (CALCUTTA)
Indian Sugar & General Engineering Corporation, Yamunanagar. (YAMUNANAGAR)

Italy

Acciaieria & Tubificio di Brescia, Brescia. (BRESCIA)
Ansaldo Meccanico Nucleare S.p.A., Stabilimento Meccanico, Genoa. (GENOA)
Belleli R., Mantova. (BRESCIA)
Bonaldi D. & Co., S.p.A., Crema. (MILAN)
Bosco, A., Officine Meccaniche e Fonderie, Terni. (NAPLES)
Franco Tosi, S.p.A., Legnano. (MILAN)
Nuovo Pignone, Industrie Meccaniche e Fonderia S.p.A., Stabilimento di Massa, Apuania. (LA SPEZIA)
Terni, Societa per l'Industria e l'Elettricita, Terni. (NAPLES)

Japan

Babcock-Hitachi K.K., Kure Works, Kure. (HIROSHIMA)
Babcock-Hitachi K.K., Yokohama. (YOKOHAMA)
Chiyoda Chemical Engineering & Construction Co., Ltd., Kawasaki Factory, Kawasaki. (YOKOHAMA)
Fuji Electric Co., Ltd., Kawasaki Factory, Kawasaki. (YOKOHAMA)
Hirano Iron Works Co., Ltd., Osaka. (KOBE)
Hitachi Shipbuilding & Eng. Co., Ltd., Innoshima Shipyard, Innoshima. (KOBE)
Hitachi Shipbuilding & Eng. Co., Ltd., Sakurajima Works, Osaka. (KOBE)
Ishikawajima-Harima Heavy Industries Co., Ltd., Aioi. (KOBE)
Ishikawajima-Harima Heavy Industries Co., Ltd., Nagoya Shipyard. (KOBE)
Ishikawajima-Harima Heavy Industries Co., Ltd., Tokyo. (YOKOHAMA)
Kawasaki Heavy Industries, Ltd., Kawasaki. (YOKOHAMA)
Kawasaki Heavy Industries, Ltd., Kobe. (KOBE)
Kobe Steel, Ltd., Okubo Plant, Akashi City. (KOBE)
Maizuru Jukogyo Ltd., Maizuru Shipyard, Maizuru. (KOBE)
Mitsubishi Heavy Industries Ltd., Kobe Shipyard & Engine Works, Kobe. (KOBE)
Mitsubishi Heavy Industries Ltd., Hiroshima Shipyard & Engine Works, Hiroshima. (HIROSHIMA)
Mitsubishi Heavy Industries Ltd., Nagasaki Shipyard & Engine Works, Nagasaki. (NAGASAKI)
Mitsubishi Heavy Industries Ltd., Yokohama Shipyard & Engine Works, Yokohama. (YOKOHAMA)
Mitsui Shipbuilding & Engineering Co., Ltd., Fujinagata Works, Osaka. (KOBE)
Mitsui Shipbuilding & Engineering Co., Ltd., Tamano. (KOBE)
Nippon Kokan K.K., Tsurumi Shipyard. (YOKOHAMA)
Sasebo Heavy Industries, Co., Ltd., Sasebo. (SASEBO)
Sumitomo Shipbuilding & Machinery Co., Ltd., Uraga Machinery Division, Yokosuka. (YOKOHAMA)

Norway

Elektrisk Sveisning A/S, Toyenbekken 34, Oslo. (OSLO)
Fredriksstad Mek. Verksted, Fredrikstad. (OSLO)
Kvaerner Brug A/S, Oslo. (OSLO)

Poland

Huta Ferrum, Katowice. (GDANSK)
Sosnowieckie Zaklady Budowy Kotlow, Sosnowiec. (KATOWICE)
Stocznia Gdansk (Gdansk Shipbuilding, Marine Engineering & Boiler Works), Gdansk. (GDANSK)

South Africa

Barlows Heavy Engineering Ltd., Benoni, Transvaal. (VEREENIGING)
Thompson, John, Africa (Pty.) Ltd., Bellville, Cape Province. (CAPE TOWN)
Vecor Heavy Engineering Ltd., Duncanville Works, Houtkop Road, Duncanville. (VEREENIGING)

Spain

Empresa Nacional Bazan, El Ferrol. (EL FERROL)
La Maquinista Terrestre y Maritima S.A., Barcelona. (BARCELONA)
S.E. de C. Babcock & Wilcox S.A., Galindo Works, Bilbao. (BILBAO)

Sweden

Aktiebolaget Gotaverken, Gothenburg. (GOTHENBURG)
Avesta Jernverks A/B, Avesta. (STOCKHOLM)
Eriksbergs Mek. Verkstads A/B, Gothenburg. (GOTHENBURG)
Karlskronavarvet A/B, Karlskrona. (MALMO)
Karlstads Mek. Werkstad A/B, Karlstad. (GOTHENBURG)
Kockums Mek. Verkstads A/B., Malmo. (MALMO)
Motala Verkstad A/B, Motala. (GOTHENBURG)
Uddcomb Sweden A/B, Degerfors. (GOTHENBURG)

Switzerland

Brown, Boveri Ltd., Baden. (WINTERTHUR)
Sulzer Brothers Ltd., Winterthur. (WINTERTHUR)

August, 1970

U.S.A.

Babcock & Wilcox Co., Barberton, Ohio. (CLEVELAND)
Chicago Bridge & Iron Co., Birmingham, Alabama. (MOBILE)
Combustion Engineering Co., Inc., Chattanooga, Tennessee. (MOBILE)
Foster Wheeler Corporation, Mountaintop, Pa. (PHILADELPHIA)

Yugoslavia

Djuro Djakovic, Slavonski Brod. (RIJEKA)
Energionvest T.A.T., Sarajevo. (RIJEKA)
Tvornica Parnih Kotlova, Zagreb. (RIJEKA)

Chapter K

SPARE GEAR FOR STEAM AND OIL ENGINE MACHINERY INSTALLATIONS

SPARE PARTS FOR THE FOLLOWING ITEMS, SO FAR AS THEY ARE APPLICABLE, ARE TO BE CARRIED. THE SPARE PARTS ARE TO BE REPLACED OR MADE GOOD BY THE OWNERS AS OPPORTUNITY OCCURS.

In the case of ships with multi-engine installations, the spare parts required need only be carried for one engine.

ITEM NO.	ITEM	SPARE PARTS REQUIRED TO BE CARRIED		
		NUMBER REQUIRED		SPARE PARTS
		SHIPS FOR UNRESTRICTED SERVICE	SHIPS FOR RESTRICTED SERVICE	
	MAIN PROPELLING MACHINERY			
	STEAM RECIPROCATING ENGINES (*See also* item 25)			
1	Connecting Rod Bearings	1	1	Bottom end bearing complete with liners, bolts and nuts.
		1	1	Top end bearing complete with liners, bolts and nuts for one connecting rod.
2	Piston Rings	1 set	1 set	Rings and springs for H.P. piston.
3	Piston Valve Rings	1 set	—	Rings and springs, of each size fitted.
4	Piston Rod Metallic Packing	1	—	Complete set of packing for H.P. piston rod and valve spindle.
5	Poppet Valves	1	—	Valve complete with cage, spindle and bush, of each size fitted, together with rollers and springs.
	STEAM TURBINES (*See also* item 25)			
6	Bearing Bushes	1	—	Complete bearing bush, of each size and type fitted, for the rotor, pinion and gear wheel shafts, for one engine.
7	Turbine Thrust	1 set	1 set	Pads of each size for one face of Michell type thrust, or rings for turbine adjusting block, of each size fitted for one engine. Assorted liners for 1 block where fitted.
	OIL ENGINES (*See also* item 25)			
8	Main Bearings	1	—	Main bearings or shells for one bearing of each size and type fitted, complete with shims, bolts and nuts.
9	Cylinder Liner	1	—	Cylinder liner, complete with joint rings and gaskets.
10	Cylinder Cover	1	—	Cylinder cover, complete with valves, joint rings and gaskets. For engines without covers, the respective valves for one cylinder unit.
		½ set	—	Cylinder cover bolts and nuts, for one cylinder.

ITEM NO.	ITEM	SPARE PARTS REQUIRED TO BE CARRIED		
		NUMBER REQUIRED		SPARE PARTS
		SHIPS FOR UNRESTRICTED SERVICE	SHIPS FOR RESTRICTED SERVICE	
11	Cylinder Valves	2 sets	1 set	Exhaust valves, complete with casings, seats, springs and other fittings for one cylinder.
		1 set	1 set	Air inlet valves, complete with casings, seats, springs and other fittings for one cylinder.
		1	1	Starting air valve, complete with casing, seat, springs and other fittings.
		1	1	Relief valve, complete.
		1 set	½ set	Fuel valves of each size and type fitted, complete with all fittings, for one engine.
12	Connecting Rod Bearings	1 set	—	Bottom end bearings or shells of each size and type fitted, complete with shims, bolts and nuts, for one cylinder.
		1 set	—	Top end bearings or shells of each size and type fitted, complete with shims, bolts and nuts, for one cylinder.
13	Pistons	1	—	Crosshead type: Piston of each type fitted, complete with piston rod, stuffing box, skirt, rings, studs and nuts.
		1	—	Trunk piston type: Piston of each type fitted, complete with skirt, rings, studs, nuts, gudgeon pin and connecting rod.
14	Piston Rings	1 set	—	Piston rings, for one cylinder.
15	Piston Cooling	1 set	—	Telescopic cooling pipes and fittings or their equivalent, for one cylinder unit.
16	Gear and Chain for Camshaft Drives	1 set	—	Gear wheel drive: Wheels for the camshaft drive of one engine.
		6	—	Chain drive: Separate links with pins and rollers of each size and type fitted.
		1 set	—	Bearing bushes of each type fitted.
17	Cylinder Lubricators	1	—	Lubricator complete, of the largest size, with its chain drive or gear wheels.
18	Fuel Injection Pumps	1	—	Fuel pump complete, or, when replacement at sea is practicable, a complete set of working parts for one pump (plunger, sleeve, valves, springs, etc.)
19	Fuel Injection Piping	1	—	High pressure fuel pipe of each size and shape fitted, complete with couplings.
20	Scavenge Blowers (including turbo-chargers)	1 set	—	Rotors, rotor shafts, bearings, nozzle rings and gear wheels or equivalent working parts if of other types. NOTE: Where an engine with one blower out of action can be manœuvred satisfactorily spare parts may be omitted.
21	Scavenging System	1 set	—	Suction and delivery valves for one pump of each type fitted.
22	Reduction and/or Reverse Gear	1 set	—	Complete bearing bush, of each size fitted in the gear case assembly.
		1 set	—	Roller or ball race, of each size fitted in the gear case assembly.

ITEM NO.	ITEM	SPARE PARTS REQUIRED TO BE CARRIED		
		NUMBER REQUIRED		SPARE PARTS
		SHIPS FOR UNRESTRICTED SERVICE	SHIPS FOR RESTRICTED SERVICE	
23	Main Engine Driven Air Compressors	1 set	—	Piston rings of each size fitted.
		½ set	—	Suction and delivery valves complete of each size fitted.
24	Gaskets and Packings	—	1 set	Special gaskets and packings of each size and type fitted for cylinder covers and cylinder liners for one cylinder.
	APPLICABLE TO ALL TYPES OF MAIN ENGINES			
25	Main Thrust Blocks	1 set	1 set	Pads for one face of Michell type thrust block or
		1	1	Complete white metal thrust shoe of solid ring type or
		1	1	Inner and outer race with rollers where roller thrust bearings are fitted.
	ELECTRIC PROPELLING MACHINERY	For items of spare gear to be carried, *see* M 21.		

AUXILIARY MACHINERY

Where additional units of adequate capacity are fitted no spare gear is required.

AUXILIARY OIL ENGINES For each type of engine required for essential services.

ITEM NO.	ITEM	SHIPS FOR UNRESTRICTED SERVICE	SHIPS FOR RESTRICTED SERVICE	SPARE PARTS
26	Main Bearings	1	—	Main bearings or shells for one bearing of each size and type fitted, complete with shims, bolts and nuts.
27	Cylinder Valves	2 sets	—	Exhaust valves, complete with casings, seats, springs and other fittings for one cylinder.
		1 set	—	Air inlet valves, complete with casings, seats, springs and other fittings for one cylinder.
		1	—	Starting air valve, complete with casing, seat, springs and other fittings.
		1	—	Relief valve, complete.
		½ set	—	Fuel valves of each size and type fitted, complete, with all fittings, for one engine.
28	Connecting Rod Bearings	1 set	—	Bottom end bearings or shells of each size and type fitted, complete with shims, bolts and nuts, for one cylinder.
		1 set	—	Top end bearings or shells of each type fitted, complete with shims, bolts and nuts, for one cylinder.
		1 set	—	Trunk piston type: gudgeon pin with bush for one cylinder.
29	Piston Rings	1 set	—	Piston rings, for one cylinder.
30	Piston Cooling	1 set	—	Telescopic cooling pipes and fittings or their equivalent, for one cylinder unit.
31	Fuel Injection Pumps	1	—	Fuel pump complete, or, when replacement at sea is practicable, a complete set of working parts for one pump (plunger, sleeve, valve springs, etc.)

ITEM NO.	ITEM	SPARE PARTS REQUIRED TO BE CARRIED		
		NUMBER REQUIRED		SPARE PARTS
		SHIPS FOR UN-RESTRICTED SERVICE	SHIPS FOR RESTRICTED SERVICE	
32	Fuel Injection Piping	1	—	High pressure fuel pipe of each size and shape fitted, complete with couplings.
33	Gaskets and Packings	1 set	—	Special gaskets and packings of each size and type fitted, for cylinder covers and cylinder liners for one cylinder.
	AUXILIARY STEAM ENGINES	For each size of engine required for essential services.		
34	Connecting Rod Bearings	1	1	Bottom end bearing complete with liners, bolts and nuts.
		1	1	Top end bearing complete with liners, bolts and nuts.
35	Piston Rings	1 set	1 set	Rings.
	TURBINES DRIVING ESSENTIAL AUXILIARIES	Spare gear to be the same as for main steam turbines in so far as applicable.		
	AUXILIARY AIR COMPRESSOR			
36	Piston Rings	1 set	1 set	Rings, of each size fitted, for one piston.
37	Valves	½ set	½ set	Suction and delivery valves, complete, of each size fitted.
	ELECTRICAL EQUIPMENT	For items of spare gear to be carried, *see* M 21.		
	REFRIGERATING INSTALLATIONS IN SHIPS	For items of spare gear to be carried, *see* N 6.		

BOILERS

	MAIN AND AUXILIARY BOILERS (*See* G 103)			
38	Tube Stoppers or Plugs	20	10	Tube stoppers or plugs, of each size used, for boiler, superheater and economiser tubes.
39	Fire Bars	1 set	½ set	Fire bars for one boiler, where coal fired.
40	Oil Fuel Burners	1 set	1 set	Oil fuel burners complete, for one boiler.
41	Gauge Glasses	2 sets per boiler	2 sets per boiler	Gauge glasses of round type.
		1 set for every two boilers	1 set for every two boilers	Gauge glasses of flat type.

Chapter L

CONTROL ENGINEERING EQUIPMENT

Section 1

GENERAL REQUIREMENTS

101 (*a*) This Chapter applies to both passenger ships and cargo ships, and is in addition to other relevant sections of the Rules.

(*b*) Whilst these requirements satisfy the regulations of the International Convention for the Safety of Life at Sea, 1960, attention should also be given to any relevant statutory requirements of the National Authority of the country in which the ship is to be registered.

(*c*) This Chapter states requirements for systems of automatic or remote control which may be used for controlling the machinery contained in 102(b).

The design and installation of other control equipment is to be such that there is no risk of danger due to its failure.

(*d*) The details of control systems will vary with the type of machinery being controlled and special consideration will be given to each case.

Plans

102 (*a*) Where control systems are applied to essential machinery or equipment as listed in 102(b) plans are to be submitted in triplicate. They are to include or be accompanied by:—

- Details of operating medium, i.e., pneumatic, hydraulic or electric, including standby sources of power.
- Description and/or block diagram showing method of operation.
- Line diagrams of control circuits whether open or closed loop.
- List of points monitored.
- List of alarm points.
- List of control points.
- Test facilities provided.
- Test schedules.
- Maintenance programmes, e.g., whether of modular construction so that repair by replacement is intended.
- Spare gear, as recommended by the Manufacturer.

(*b*) **Control Systems for which Plans are required**:—

- Ballast systems for dry cargo ships.
- Bilge systems.
- Cargo pumping systems for tankers.
- Controllable pitch propellers.
- Electric generating plant.
- Evaporating and distilling systems for use with main steam machinery.
- Fire detection systems.
- Fire extinguishing systems.
- Fuel oil transfer and storage systems.
- Main propelling machinery including essential auxiliaries.
- Steam raising plant.
- Steel hatch covers.
- Windlass.

(*c*) **Alarm Systems**

Details of the overall alarm system linking main control station, bridge area and accommodation are to be submitted.

(*d*) **Control Stations**

Details of control stations, including bridge control, are to be submitted.

(*e*) **Standard Systems**

Where it is intended to employ a system which has been previously approved it will be sufficient to refer to such previous approval. In such cases additional plans are not required.

Alarm and Control Equipment

103 Major units of equipment are to be surveyed at the manufacturer's works. Examples of such major units are:—

- Bridge control consoles.
- Boiler control consoles.
- Display, alarm and data processing consoles.

The workmanship is to be to the Surveyor's satisfaction and the Surveyor is to be satisfied that the components are suitable for the intended environment.

The Society will issue lists of approved components which have been successfully type tested for environment. A copy of the Society's Environmental Test Specification will be furnished on application.

Assessment of performance parameters, such as accuracy, rangeability and the like, are to be in accordance with an acceptable national or international standard.

Components used in control systems should, wherever practicable, be selected from the lists of approved equipment to be issued by the Society.

Alterations or Additions

104 When an alteration or addition to the approved system(s) is proposed plans are to be submitted for approval. The alterations or additions are to be carried out under the inspection and to the satisfaction of the Surveyors.

Section 2

UNATTENDED MACHINERY SPACES—"UMS" NOTATION (*See* B 301(*c*))

Essential Safety Features

201 Where it is proposed to operate the ship with unattended machinery spaces, no matter what period is envisaged, the safety features in 202 to 209 inclusive are to be installed.

Bridge Control

202 (*a*) Means are to be provided to ensure satisfactory control of propulsion from the bridge.

(*b*) Instrumentation to indicate the following is to be fitted on the bridge:—

(i) Propeller speed,

(ii) Direction of rotation of propeller for a fixed pitch propeller or pitch position for a controllable pitch propeller,

(iii) Where a main propulsion engine is started from the bridge, indication that sufficient air pressure is available for manœuvring the engine.

Alarm System for Propulsion Machinery and Other Essential Machinery

203 An alarm system which will provide warning of faults in the essential machinery is to be installed. The system is to satisfy the following requirements:—

(*a*) Machinery faults are to be indicated at the control station for machinery (*see* L 3).

(*b*) Engineering personnel is/are made aware that a machinery fault has occurred.

(*c*) If the bridge navigating officer of the watch is the sole watchkeeper, then in the event of a machinery fault being monitored at the control station for machinery (*see* 204), the alarm system is to be such that this watchkeeper is made aware when:—

(i) a machinery fault has occurred,

(ii) the machinery fault is being attended to,

(iii) the machinery fault has been rectified. Alternatively, the system of communication required by 204(b) may be used for this purpose.

(*d*) The alarm system should, as far as practicable, be designed with self-monitoring properties.

(*e*) Failure of power supply to the alarm system is to be indicated.

(*f*) All alarms are to be both audible and visual. If arrangements are fitted to silence audible alarms they are not to extinguish visual alarms.

(*g*) If the audible alarm has been silenced and a second fault occurs before the first can be rectified the audible alarm is again to operate.

Control Stations for Machinery

204 (*a*) A system of alarm displays is to be provided which readily ensures identification of faults in the machinery. For example, this may be provided by displays at a main control station or, alternatively, at subsidiary control stations. In the latter case, a master display is to be provided showing which of the subsidiary control stations is indicating a fault condition.

(*b*) At the main control station (if provided) or close to the subsidiary stations (if fitted) there is to be provided means of communication with the bridge area, the accommodation for engineering personnel and, if necessary, the machinery spaces.

The main control station and any other station from which the main propulsion machinery can be controlled are to be provided with means to indicate which station is in control.

Fire Detection Alarm System

205 (*a*) An automatic fire detection system is to be fitted in the machinery spaces together with an audible and visual alarm system.

(*b*) A fire detector indicator panel is to be located in the navigating bridge area or in such a position that a fire in the machinery spaces will not render it inoperative. Where the machinery spaces are made up of separate compartments, e.g., generator rooms, purifier rooms, etc., the fire detector indicator panel should be sectionalised.

(*c*) The audible fire alarm is to have a characteristic tone which distinguishes it from the alarm system required by 203. The audible fire alarm is to be audible on all parts of the navigating bridge and in accommodation areas.

(*d*) The alarm system should, as far as practicable, be designed with self-monitoring properties.

(*e*) Failure of power supply to the alarm system is to be indicated.

(*f*) Detector heads of an approved type are to be located in the machinery spaces so that all potential fire outbreak points are guarded.

(*g*) The fire detection system is to be capable of being tested.

(*h*) It is to be demonstrated to the Surveyor's satisfaction that detector heads are located so that air currents will not render the system ineffective at sea and in port.

(*j*) A drawing showing the location of the fire detector heads and the fire detector indicator panel is to be submitted.

Fire Prevention

206 (*a*) Means are to be provided to prevent leaks from high pressure oil fuel pipes dripping or spraying onto hot surfaces or, if applicable, into turbo-charger inlets. Such leakage preferably should be led to a collector tank fitted in a safe position with an alarm to indicate that leakage is taking place.

(*b*) Means are to be provided to eliminate the possibility of overflow from daily service oil fuel tanks into the machinery spaces, and to safeguard against overflow of oil from the daily service oil fuel tanks through the air pipe. A suitable alarm may satisfy this latter requirement.

Bilge Level Alarm System

207 (*a*) An alarm system is to be provided to warn that liquid in the machinery space bilges has reached a pre-determined level and is to comply with 203. This level is to be sufficiently low to prevent liquid from overflowing from the bilges on to the tank top. In ships above 2000 gross tons at least two independent systems of level detection are to be provided.

(*b*) Automatic starting of bilge pumps is not generally acceptable for the following reasons:—

(i) Leakage of liquid, either oil or water, into the bilges may be caused by a fault condition. If the bilge pump starts automatically, discovery of the fault condition may be delayed,

(ii) Considerations of sea pollution. Attention is drawn to the International Convention for the Prevention of Pollution of the Sea by Oil, 1954, and subsequent amendments.

However, arrangements with automatic starting may be considered, provided the Society is satisfied that the above requirements are met.

Supply of Electric Power

208 Arrangements are to be provided so that essential lighting in the machinery space is switched on automatically if the normal supply of electric power should fail.

Local Control of Essential Machinery

209 Arrangements are to be such that the essential machinery can be operated with the system of bridge control or any automatic controls out of action.

Section 3

ALARMS AND AUTOMATIC CONTROLS FOR PROPULSION AND OTHER ESSENTIAL MACHINERY—"UMS" NOTATION

General

301 Machinery for propulsion and other essential services is to be protected by the alarm system required by L 203, and machinery faults are to be identifiable at the main control station for machinery as required by L 204.

The minimum requirements for the alarm systems and automatic stop or shut down of different types of machinery installations are given in 302 to 305.

OIL ENGINES FOR PROPULSION PURPOSES

302 (*a*) The following systems are to be provided with alarms:—

System	*Alarm*
Lubricating oil for the engine including turbo blower and gearing	High temperature Loss of pressure
Cooling system(s)	High temperature Loss of pressure or loss of flow
Exhaust gas	High temperature
Starting air	Loss of pressure
Daily service fuel tanks	Low level High level—*See* L 206(b)
Sterntube bearing lubricating oil system	Low level or high temperature in bearing
Thrust bearing	High temperature

(b) **Automatic Stop**

In the case of the lubricating oil system, in addition to alarm indication as required by 302(a), the engine is to be stopped automatically for complete loss of lubricating oil. The circuit employed for this automatic stop is to be additional to the alarm circuit required by 302(a).

STEAM TURBINE MACHINERY FOR PROPULSION PURPOSES

303 (*a*) The following systems are to be provided with alarms:—

System	*Alarm*
Lubricating oil for the turbines and gearing	Loss of pressure
Turbine and gearing bearings	High temperature
Main condenser	Loss of vacuum
Astern turbine	High temperature
Cooling systems	High temperature Loss of pressure
Sterntube bearing lubricating oil	Low level or high temperature in bearing
Main thrust bearing	High temperature

(*b*) **Automatic Stop**

In the case of the lubricating oil system, in addition to alarm indication as required by 303(a), steam is to be shut off automatically from the turbine(s) for complete loss of lubricating oil. The circuit employed for this automatic shut off is to be additional to the alarm circuit required by 303(a).

(*c*) **Lubricating Oil Supply**

Where electric power is normally used to supply lubricating oil to the turbines and gearing, means are to be provided to safeguard the turbines from possible damage caused by rotation from propeller water torque if the normally connected supply of electric power should fail.

MAIN AND AUXILIARY BOILERS

Alarm and Fuel Shut-off Systems

304 (*a*) Two independent systems of water level detection are to be fitted which will operate alarms and shut off automatically the oil supply to the burners when the water level falls to a pre-determined low level. Both independent detectors are to be arranged to operate one actuator for fuel shut-off.

(*b*) The oil fuel is to be shut off automatically from the burners, and alarms are to operate either on flame failure or failure of combustion air supply detected by either low pressure at fan outlet or stopping of fan motor.

(*c*) Where the burner flame(s) is/are extinguished and re-ignited automatically in response to steam demand then after total flame failure re-ignition shall not take place until the furnace has been purged of explosive gases.

(*d*) A low level alarm is to be fitted for the daily service oil fuel tanks. For high level of overflow alarm, *see* L 206(b).

NOTE.—Only one independent system of water level detection, alarm and automatic oil supply shut-off, as described in 304(a), need be fitted in the case of small forced circulation or recirculation coiled water tube "package type" auxiliary boilers.

ELECTRIC GENERATING PLANT—"UMS" NOTATION

305 Alarms are to be provided to give warning of the following conditions:—

- Operation of load shedding arrangements (*see* M 615).
- Low voltage.
- High voltage.
- Low frequency.
- Low lubricating oil pressure.
- Low cooling water pressure or high cooling water temperature or loss of flow.

For parallel running a.c. generators, the alarms for low voltage, high voltage and low frequency may be satisfied by suitable system design.

Section 4

CONTROLLABLE PITCH PROPELLERS—"UMS" NOTATION

401 (*a*) A pitch indicator is to be fitted at each station from which it is possible to control the pitch of the propeller.

(*b*) Means are to be provided to prevent the engine and shafting being subjected to excessive torque due to changes in propeller pitch; alternatively, an engine overload indicator may be fitted at each station from which it is possible to control the pitch of the propeller.

(*c*) A stand-by or alternative power source of actuating medium for controlling the pitch of the propeller blades is to be fitted.

Section 5

CRITICAL SPEEDS—"UMS" NOTATION

501 Prolonged running in a restricted speed range is to be prevented automatically; alternatively, indication of restricted speed ranges is to be provided at each control station.

Section 6

REQUIREMENTS FOR UNATTENDED MACHINERY SPACES IN TUGS, COASTERS AND OTHER SMALL SHIPS HAVING PROPULSION MACHINERY OF LESS THAN 2000 SHP—"UMS" NOTATION

601 The requirements of L 2 are to be applied. In addition, the alarm system is to indicate the following:—

(*a*) Failure of control medium for bridge control system.

(*b*) Low lubricating oil pressure for main and auxiliary diesel engines.

(*c*) Low cooling water pressure or high cooling water temperature for main and auxiliary diesel engines.

(*d*) Boiler flame failure and low water level independently.

Section 7

ATTENDED MACHINERY SPACES

701 Where it is proposed to operate the ship with attended machinery spaces, and control equipment is fitted to the essential machinery, means are to be provided so that such machinery can be operated with any automatic control system(s) out of action.

Section 8

CARGO, BILGE AND BALLAST VALVES WITH REMOTE OR AUTOMATIC CONTROL

801 Where cargo or ballast valves are operated by remote or automatic control and bilge valves by remote control, the system of control should include the following safety features:—

(*a*) Failure of actuator power should not permit a valve to open inadvertently.

(*b*) Indication is to be provided at the remote control station for these services that the valve is open or closed.

(*c*) Equipment located in places which may be flooded should be capable of operating when submerged.

(*d*) A secondary means of operating the valves, which may be manual control, is to be provided. (*See* E 250.)

Section 9

TRIALS

901 Before a new installation, or any alteration or addition to an existing installation, is put into service trials are to be carried out. These trials are in addition to any acceptance tests which may have been carried out at the manufacturers' works and are to be based on the test schedules list called for in L 102.

It will be expected that most of these trials will be carried out before the sea trials of the ship.

15th January, 1970

Chapter M

ELECTRICAL EQUIPMENT AND ELECTRIC PROPELLING MACHINERY

Section 1

GENERAL REQUIREMENTS

101 (*a*) The requirements of this Chapter apply to passenger ships and cargo ships except where otherwise stated. While these requirements are considered to meet those of the 1960 Safety of Life at Sea Convention, attention should be given to any relevant statutory regulations of the National Authority of the country in which the ship is to be registered.

(*b*) In passenger ships services essential for safety are to be maintained under emergency conditions and the safety of ship and personnel from electrical hazards is to be assured.

(*c*) This Chapter states requirements for those features of the electrical installation which are considered essential for the safety of the ship. The design and installation of other equipment is to be such that there is no risk of fire due to its failure. It must, as a minimum, comply with a national or international standard.

(*d*) The Committee will be prepared to give consideration to special cases or to arrangements which are equivalent to the Rules. Consideration will also be given to the electrical arrangements of small ships and ships to be assigned class notations for restricted or special services.

(*e*) Electrical installations for propulsion and auxiliary services are to be constructed and installed in accordance with the relevant sections of this Chapter and are to be inspected and tested by the Surveyors.

Plans

102 The following plans and particulars are to be submitted in triplicate, for consideration:—

PROPULSION EQUIPMENT

Plans of generators, motors and seatings together with diagrams of control gear, cables and circuits, and particulars of voltage, current, power and speed with a key diagram and explanation of the system in relation to the requirements of M 17.

ELECTRIC SLIP COUPLINGS

Plans showing the scantlings and construction of the couplings together with diagrams of electrical components, switchgear and control gear.

ELECTRICAL EQUIPMENT (other than propulsion equipment)

The arrangement plan and circuit diagram of the switchboard(s). Diagrams of the wiring system including cable sizes, type of insulation, normal working current in the circuits and the capacity, type and make of protective devices. Calculations of short-circuit currents at main busbars, sub-switchboard busbars and the secondary side of transformers are to be submitted. (*See* M 611.)

WELDING ON SHAFTS

Where welding is to be applied to shafts of machines for essential services for securing armature arms or spiders, plans showing the construction are to be submitted for consideration.

PRIME MOVERS

See G 104.

TANKERS (compartments in between deck spaces)

See M 1605.

CENTRALISED, BRIDGE OR AUTOMATIC CONTROLS

See F 105 and Chapter L.

Additions or Alterations

103 An addition, temporary or permanent, is not to be made to the approved load of an existing installation until it has been ascertained that the current-carrying capacity and the condition of the existing accessories, conductors and switchgear are adequate for the increased load. (*See* C 108.)

Plans are to be submitted for approval and the alterations or additions are to be carried out under the inspection and to the satisfaction of the Surveyors.

Application

104 Except where a specific statement is made to the contrary all requirements of this Chapter are applicable to both alternating current and direct current installations.

105 D.C. equipment is to operate satisfactorily under voltage fluctuations of plus 6 per cent and minus 10 per cent.

A.C. equipment is to operate satisfactorily under voltage fluctuations of plus 6 per cent and minus 10 per cent at rated frequency and under frequency fluctuations of plus or minus 2,5 per cent at rated voltage.

Contactors and similar equipment are not to drop out at or above 85 per cent rated voltage.

Ambient Temperatures

106 The following cooling air and cooling water temperatures are applicable in ships classed for:—

(*a*) UNRESTRICTED SERVICE

(i) Primary cooling water supply	30°C (86°F)
(ii) Cooling air temperature	45°C (113°F)

(*b*) RESTRICTED SERVICE (*See* B 110 and B 111)

Vessels intended solely for use in northern or southern waters outside the tropical belt.

(i) Primary cooling water supply	25°C (77°F)
(ii) Cooling air temperature	40°C (104°F)

Location and Construction

107 Electrical equipment is to be accessibly placed clear of flammable material in well ventilated, adequately lighted spaces in which flammable gases cannot accumulate and where it is not exposed to risk of mechanical injury or damage from water, steam or oil. Where necessarily exposed to such risks the equipment is to be suitably constructed or enclosed. Live parts are to be guarded where necessary.

Insulating materials and insulated windings are to be resistant to tracking, moisture, sea air and oil vapour unless special precautions are taken to protect them.

Equipment is not to remain alive through the control circuits and/or pilot lamps when switched off by the control switch. This does not apply to synchronizing switches and/or plugs.

The operation of all electrical equipment and the lubricating arrangements are to be efficient under such conditions of vibration and shock as arise in normal practice, and with the ship inclined from the normal at any angle up to 15 degrees transversely, when pitching 10 degrees longitudinally and when rolling up to 22,5 degrees from the vertical.

All nuts and screws used in connection with current-carrying parts and working parts are to be effectively locked.

Conductors and equipment are to be placed at such a distance from the magnetic compasses or are to be so disposed that the interfering magnetic field is negligible even when circuits are switched on and off.

Where electric power is used for propulsion, the equipment is to be arranged so that it will operate satisfactorily in the event of partial flooding by bilge water above the tank top up to floor plate level. (*See* E 223 and E 224.)

Earthing

108 (*a*) Non-current-carrying metal parts of electrical equipment are to be effectively earthed. Where earthing connections are necessary they are to be of copper or other approved material and are to be protected against damage and, where necessary, electrolytic action. In general, they are to be equal to the cross section of the current-carrying conductor up to 16 mm² (0·0225 in²). Above this figure they are to be equal to at least half the cross section of the current-carrying conductor with a minimum of 16 mm² (0.0225 in²).

(*b*) PORTABLE EQUIPMENT—Metal frames of all portable electric lamps, tools and similar apparatus supplied as ship's equipment and rated in excess of 55 V are to be earthed through a suitable conductor unless equivalent safety provisions are made such as by double insulation or by an isolating transformer.

Flameproof and Intrinsically Safe Equipment

109 Where risk of explosion might otherwise arise, equipment is to be of flameproof or intrinsically safe type.

Where equipment is required to be of flameproof or intrinsically safe type and equipment of suitable type is obtainable which has been type tested and approved by a competent independent Testing Authority, it will be sufficient to furnish a copy of the relevant certificate, provided that there is no departure from the design so tested and approved.

NOTE:—

(i) A flameproof enclosure is one which will withstand without injury any explosion of the prescribed flammable gas that may occur within it under practical conditions of operation, and will prevent the transmission of flame such as will ignite the flammable gas in the surrounding atmosphere.

(ii) Intrinsically safe apparatus is to be so constructed that when installed and operated under the conditions specified by the Certifying Authority, any electrical sparking that may occur in normal working, either in the apparatus or in its associated circuit, is incapable of causing an ignition of the prescribed flammable gas or vapour.

Creepage and Clearance

110 The distances between live parts and between live parts and earthed metal whether across surfaces or in air shall be adequate for the working voltage having regard to the nature of the insulating material and the transient over-voltages developed by switch and fault conditions.

For bare busbars the following minimum clearance distances shall be observed:—

Voltage between phases or poles	Minimum clearance to earth				Minimum clearance between phases or poles			
	In air		In oil		In air		In oil	
	mm	in	mm	in	mm	in	mm	in
660 or less	16	0·625	—	—	19	0·75	—	—
2200	38	1·5	—	—	38	1·5	—	—
3300	51	2	13	0·5	51	2	19	0·75
6600	63	2·5	19	0·75	89	3·5	25	1·0

Where necessary these figures are to be increased to allow for the electro-magnetic forces involved.

Emergency Source of Power

111 An emergency source of power, capable of functioning when the ship is inclined 22,5 degrees and/or when the trim of the ship is 10 degrees, is to be installed in accordance with the following:—

Where emergency generating sets are fitted they are to be capable of being started readily when cold.

If hand starting is demonstrated to be practicable, alternative means of starting are not required. Where hand starting is not practicable other means are to be provided and, in general, should provide for not less than 12 starts in a period of 30 minutes without recourse to sources of power within the machinery space.

I PASSENGER SHIPS

(*a*) A self-contained emergency source of electric power is to be installed above the bulkhead deck and outside the machinery casings. Its location in relation to the main source or sources of electric power is to be such as to ensure that a fire or other casualty to the machinery spaces (i.e., spaces containing the main and auxiliary propelling machinery, boilers serving the needs of propulsion and all permanent coal bunkers) will not interfere with the supply or distribution of emergency power. It is not to be forward of the collision bulkhead.

(*b*) The power available is to be sufficient to supply all services necessary for the safety of passengers and crew in an emergency, due regard being paid to such services as may have to be operated simultaneously. Special consideration is to be given to emergency lighting at every boat station on deck and oversides, in all alleyways, stairways and exits, in the machinery spaces and in the control stations (i.e. spaces in which radio, main navigating or central fire recording equipment or the emergency generator is located), to fire detection and alarm systems, to the sprinkler pumps, to navigation lights and to the daylight signalling lamp, if operated from the main source of power. The power is to be adequate for a period of 36 hours, except that, in ships engaged regularly on voyages of short duration a lesser supply will be specially considered.

(*c*) The emergency source of power is to be either:—

(i) A generator driven by a suitable prime mover with an independent fuel supply and with satisfactory starting arrangements; the fuel used is to have a flash point of not less than 43°C (110°F); or

(ii) An accumulator (storage) battery capable of carrying the emergency load without recharging or excessive voltage drop.

(*d*) (i) Where the emergency source of power is a generator a temporary source of emergency power is to be installed. This is to be an accumulator battery of sufficient capacity:—

(*a*) To supply emergency lighting continuously for 30 minutes;

(*b*) To close the watertight doors (if electrically operated) but not necessarily to close them simultaneously;

(*c*) To operate the indicators (if electrically operated) which show whether power operated watertight doors are open or closed; and

(*d*) To operate the sound signals (if electrically operated) which give warning that power operated watertight doors are about to close.

(*e*) To operate the fire detection and alarm systems.

Arrangements are to be such that the temporary source of emergency power will come into operation automatically in the event of failure of the main electrical supply.

(ii) Where the emergency source of power is an accumulator battery arrangements are to be such that emergency lighting will automatically come into operation on failure of the main lighting supply.

(*e*) An indicator is to be mounted in the machinery space, preferably on the main switchboard, to indicate when any accumulator battery fitted in accordance with this Rule is being discharged.

(*f*) (i) The emergency switchboard is to be installed as near as is practicable to the emergency source of power.

(ii) Where the emergency source of power is a generator, the emergency switchboard is to be located in the same space as the emergency source of power, unless the operation of the emergency switchboard would thereby be impaired.

(iii) No accumulator battery fitted in accordance with this Rule is to be installed in the same space as the emergency switchboard.

(iv) The emergency switchboard may be supplied from the main switchboard during normal operation.

II CARGO SHIPS

(*a*) A self-contained emergency source of power is to be fitted. This may be either:—

(i) An accumulator (storage) battery capable of carrying the emergency load without recharging or excessive voltage drop; or

(ii) A generator driven by a suitable prime mover with an independent fuel supply and with satisfactory starting arrangements; the fuel is to have a flash point not less than 43°C (110°F).

(*b*) CARGO SHIPS OF 5000T GROSS TONNAGE AND ABOVE

(i) The emergency source of power is to be located above the uppermost continuous deck and outside the machinery casings.

(ii) The power available is to be sufficient to supply all services necessary for the safety of all on board in an emergency.

Special consideration is to be given to:—

(*a*) Emergency lighting at every boat station on deck and oversides, in all alleyways, stairways and exits, in the main machinery space and the main generating set space, on the navigating bridge and in the chartroom.

(*b*) The general alarm.

(*c*) Fire detection and alarm systems.

(*d*) Navigation lights if solely electric and the daylight signalling lamp if operated by the main source of power.

(iii) The power is to be adequate for at least six hours operation.

(*c*) CARGO SHIPS OF LESS THAN 5000T GROSS TONNAGE

The emergency source of power is to be capable of supplying the illumination at launching stations and stowage positions of survival craft in addition to the emergency lighting, together with the fire detection and alarm systems.

The power available is to be adequate for at least three hours operation.

Section 2

SYSTEMS OF SUPPLY

201 The following systems of distribution may be used:—

(*a*) Parallel systems with constant pressure

DIRECT CURRENT

Two wire

Three wire with mid-wire earthed.

ALTERNATING CURRENT

Single-phase—two wire

Three-phase—

Three wire

Four wire with neutral earthed but without hull return.

Systems employing single wire with hull return may be submitted for special consideration.

(*b*) Series systems with constant current (direct current only).

202 For parallel systems with constant pressure, system voltages for both alternating current and direct current shall not exceed:—

500 V for generation, power, cooking and heating equipment permanently connected to fixed wiring.

250 V for lighting, heaters in cabins and public rooms, and other applications not mentioned above.

203 In very large alternating current installations generation and limited distribution at higher voltages (e.g., 3,3 kV) may be submitted for special consideration. (*See* M 18.)

Section 3

DIVERSITY FACTOR

301 Circuits supplying two or more final sub-circuits are to be rated in accordance with the total connected load subject, where justified, to the application of a diversity factor. Where spare ways are provided on a section or distribution board an allowance for future increase of load is to be added to the total connected load before application of any diversity factor.

The diversity factor may be applied to the calculation for size of cable and rating of switchgear and fusegear.

Winch Circuits

302 For winches the diversity factor is to be calculated and submitted.

Section 4

ROTATING MACHINERY

Governors

401 Where a turbine driven direct current generator is arranged to run in parallel with other generators a switch is to be fitted in each turbine emergency governor to open the generator circuit-breaker when the emergency governor functions. (*See* H 829.)

402 The facilities for adjusting the governor of an alternating current generating set, at normal frequency, are to be sufficiently fine to permit an adjustment of load on the engine within 5 per cent of full load.

Number of Generators

403 The number and ratings of ships' service generating sets and converting sets are to be sufficient to ensure the operation of services essential for the propulsion and safety of the ship and preservation of the cargo even when one generating set or converting set is out of service.

Rating

404 Ships' service generators, including their exciters and continuously rated motors are to be suitable for continuous duty at their full rated output at maximum cooling air or water temperature for an unlimited period, without the limits of temperature rise in 405 being exceeded. Other generators and motors are to be rated in accordance with the duty which they are to perform and when tested under rated load conditions the temperature rise is not to exceed the values in 405.

Temperature Rise

405 SHIPS FOR UNRESTRICTED SERVICE

Table M 4.1 gives the limits of temperature rise above the cooling air temperature for machines not fitted with water coolers and above the cooling water temperature for machines fitted with coolers, for machines intended to operate in ships classed for unrestricted service.

SHIPS FOR RESTRICTED SERVICE (*See* M 106)

For machines intended to operate in ships classed for restricted service as defined in M 106 the temperature rises given may be increased by 5 degC (9 degF) for all machines.

If it is known that the temperature of the cooling medium exceeds the values given in M 106 the permissible temperature rise is to be reduced by an amount equal to the excess temperature of the cooling medium.

406 The limits of temperature rise of electric slip couplings are to be in accordance with Table M 4.1 except that when a squirrel cage element is used the temperature of this element is not to reach an injurious value. The temperature of the field windings is not to exceed these limits at all speeds of operation. Arrangements for reducing the excitation of self-ventilated couplings at low operational speeds are permissible.

407 Alternating current machines of 5000 h.p. or kVA output and above, and propulsion motors having a total axial core length of 1 m or more are to have at least three embedded temperature detectors. With multi-core machines the total length is to be taken as the sum of the individual core lengths.

Overloads

408 Machines are to withstand, on test, without injury, the following momentary overloads:—

GENERATORS: An excess current of 50 per cent for 15 sec. after attaining the temperature rise corresponding to rated load, the terminal voltage being maintained as near the rated value as possible. The foregoing does not apply to the overload torque capacity of the prime mover.

TABLE M 4.1

TEMPERATURE RISE IN DEGREES CENTIGRADE

ITEM		PART OF MACHINES	Method of Measurement of Temperature	Temperature-rise °C: Air-cooled machines Class A	E	B	Water-cooled machines Class A	E	B
1.	(a)	A.C. windings of turbine-type machines having output of 5000 kVA or more	ETD or R	50	60	70	70	80	90
	(b)	A.C. windings of salient-pole and of induction machines having output of 5000 kVA or more, or having a core length of one metre or more							
2.	(a)	A.C. windings of machines smaller than in Item 1...	R	50	65	70	70	85	90
	(b)	Field windings of a.c. and d.c. machines having d.c. excitation other than those in Items 3 and 4	T	40	55	60	60	75	80
	(c)	Windings of armatures having commutators	R	—	—	80	—	—	100
3.		Field windings of turbine-type machines having d.c. excitation...	T, R	50	65	70	70	85	90
4.	(a)	Low-resistance field windings of more than one layer, and compensating windings	T, R	55	70	80	75	90	100
	(b)	Single-layer windings with exposed bare surfaces	T	50	65	70	70	85	90
5.		Permanently short-circuited insulated windings	T	The temperature-rise of these parts shall in no case reach such a value that there is a risk of injury to any insulating or other material on adjacent parts					
6.		Permanently short-circuited windings, uninsulated							
7.		Iron core and other parts not in contact with windings							
8.		Iron core and other parts in contact with windings	T	50	65	70	70	85	90
9.		Commutators and slip-rings, open or enclosed	T	50	60	70	70	80	90

Note 1.— T = Thermometer method
R = Resistance method
E.T.D. = Embedded temperature detector

Note 2.—When the commutators, sliprings or bearings of machines provided with water coolers are not in the enclosed air circuit cooled by the water cooler, but are cooled by the ambient cooling air, the permissible temperature-rise above the ambient cooling air should be the same as for ventilated machines.

Note 3.—When Class F or Class H insulation is employed the permitted temperature rises are respectively 20degC and 40degC higher than the values given for Class B insulation.

Note 4.—Classes of insulation are to be in accordance with IEC Publication No. 85 (1957)—Recommendations for the Classification of Material for the Insulation of Electrical Machinery and Apparatus in relation to their thermal stability in service.

Motors: At rated speed or, in the case of a range of speeds, at the highest and lowest speeds, under gradual increase of torque the appropriate excess torque given below. Synchronous motors and synchronous induction motors are required to withstand the excess torque without falling out of synchronism and without adjustment of the excitation circuit preset at the value corresponding to rated load.

D.C. motors	50% for 15 sec.
Polyphase A.C. synchronous motors ...	50% for 15 sec.
Polyphase A.C. synchronous induction motors	35% for 15 sec.
Polyphase A.C. induction motors ...	60% for 15 sec.

The overload tests for propulsion machines will be specially considered for each installation.

Short-Circuit

409 The stator and rotor windings of alternating current propulsion generators are to be capable of withstanding a momentary short-circuit at the terminals of the machine applied when generating full rated voltage. Ships' service generators are to be capable of withstanding the mechanical and thermal effects of fault current for the duration of any time delay which may be fitted in a tripping device for discrimination purposes.

Shaft Currents

410 Means are to be taken to prevent the ill effects of flow of currents circulating between the shaft and bearings.

Welding on Shafts

411 Where welding is applied to shafts of machines for securing armature arms or spiders, stress relieving is to be carried out after welding.

Brushgear

412 The final running position of brushgear is to be clearly and permanently marked.

Direct current motors and generators are to work with fixed brush setting from no load to the momentary overload specified without injurious sparking.

Alternating current commutator motors are to work over the specified range of load and speed without injurious sparking.

Direct Current Service Generators

413 Automatic voltage regulators are to be provided for shunt wound d.c. generators.

414 Direct current generators used for charging batteries without series-regulating resistors are to be either

(i) shunt wound

or (ii) compound wound with switches arranged so that the series winding can be switched out of service.

415 Means are to be provided at the switchboard to enable the voltage of each generator to be adjusted separately.

For each direct current generator, coupled to its prime mover, at any temperature within the working range the means provided is to be capable of adjusting the voltage at any load between no load and full load to within:—

0,5 per cent of rated voltage for generators of rating exceeding 100 kW.

1,0 per cent of rated voltage for generators of rating not exceeding 100 kW.

416 The inherent regulation of ships' service generators is to be such that the following conditions are satisfied:—

For shunt or stabilised shunt wound generators when the voltage has been set at full load, the steady voltage at no load shall not exceed 115 per cent of the full load value, and the voltage obtained at any intermediate value of load shall not exceed the no load value.

For compound wound generators with the generator at full load operating temperature and starting at 20 per cent load with voltage within 1 per cent of rated voltage, then at full load the voltage is to be within 2,5 per cent of rated voltage. The average of the ascending and descending load/voltage curves between 20 per cent load and full load is not to vary more than 4 per cent from rated voltage.

417 Generators are to be capable of delivering continuously the full load current and normal rated voltage at the terminals when running at full load engine speed at all ambient temperatures up to the specified maximum.

418 Generators required to run in parallel are to be stable from no load up to the total combined load of the group and load sharing is to be satisfactory.

419 The series winding of each two-wire generator is to be connected to the negative terminal.

420 Equaliser connections are to have a cross-sectional area appropriate to the system but in no case less than 50 per cent of that of the negative connection from the generator to the switchboard.

Alternating Current Service Generators

421 Each alternating current service generator, unless of the self-regulated type, is to be operated in conjunction with a separate automatic voltage regulator.

422 The voltage regulation of any alternating current generator with its AVR is to be such that at all loads from zero to full load the rated voltage at rated power factor is maintained under steady conditions within $\pm 2{,}5$ per cent.

423 In alternating current systems with one generator set out of action, the remaining set(s) are to have sufficient reserve capacity to permit the starting of the largest motor in the ship without causing any motor to stall or any other device to fail due to excessive voltage drop on the system.

424 Alternating current generators required to run in parallel are to be stable from 20 per cent full load (kW) up to the total combined full load (kW) of the group and load sharing is to be satisfactory.

425 When generators are operated in parallel the kVA loads of the individual generating sets are not to differ from their proportionate share of the total kVA load by more than 5 per cent of the rated kVA output of the largest machine when operating at 0,8 power factor.

Inspection and Testing

426 On machines for essential services tests are to be carried out and a certificate furnished by the manufacturer. The tests are to include temperature rise, momentary overload, high voltage, and commutation. The insulation resistance and the temperature at which it was measured shall be recorded. Shaft materials are to comply with Chapter Q.

Generators of 100 kW or over and motors of 100 h.p. and over intended for essential services are to be inspected by the Surveyors during manufacture and testing. (A list of essential services is given in M 2102). Shaft materials are to be tested in accordance with Q 6.

427 In the case of duplicate machines up to 50 kW, kVA or bhp per 1000 r.p.m. type tests of temperature rise, excess current and torque and commutation taken on a machine identical in rating and in all other essential details may be accepted in conjunction with abbreviated tests on each machine. This is not to apply to propulsion machines. For the abbreviated tests, each machine is to be run and is to be found electrically and mechanically sound and is to have a high voltage test and insulation resistance recorded.

High Voltage Test

428 A high voltage test of 1000 V plus 2 × rated voltage with a minimum of 2000 V is to be applied to new machines preferably at the conclusion of the temperature rise test. The test is to be applied between the windings and the frame with the core connected to the frame and to any windings (or sections of windings) not under test. Where both ends of each phase are brought out to accessible separate terminals each phase is to be tested separately. The test is to be made with alternating voltage at any convenient frequency between 25 and 100 cycles per second of approximately sine wave form. The test is to be commenced at a voltage of about one-third the test voltage and is to be increased to full value as rapidly as is consistent with its value being indicated by the measuring instrument. The full test voltage is then to be maintained for one minute, and then reduced to one-third full value before switching off.

When it is desired to make additional high voltage tests on a machine which has already passed its tests the voltage of such additional tests is to be 75 per cent of the figure given above.

Motors for Refrigerated Cargo Services

429 Motors intended for coupling to fans for the circulation of air in refrigerated cargo spaces are to be inspected by the Surveyors during manufacture and testing.

Plans showing the construction of the motors are to be submitted for consideration.

Fan motors fitted in the air stream are to be totally enclosed or otherwise suitably enclosed to withstand the effects of excessive moisture where they are fitted between the two sections of a cooler or where the air from the cooler passes over the motor.

The Surveyors will witness a type test on the first motor of each size and type and works test certificates are to be supplied for the remainder. This type test may also be accepted for repeat orders of motors identical in all essential respects provided cross-references are given in the works test certificates. Type tests need not be carried out for motors of the same frame size as one previously tested for higher output.

Where motors are mounted in the air stream but are to be tested in still air conditions generally two conditions arise:—

(i) The motor may be open at one end or both ends when tested but totally enclosed when mounted in the air stream. In such cases a type test should be carried out under working conditions, i.e., in the trunking with the fan and fairings in place, or alternatively, calculations furnished to show that the Rules for temperature rise are complied with.

(ii) The motor may be totally enclosed but with streamlined fairings. These may be accepted if, when tested in still air, the temperature rises are within the requirements of the Rules for totally enclosed motors. If they are outside these requirements the procedure in (i) is to be followed.

Electric Slip Couplings

430 Slip couplings are to be inspected by the Surveyors during manufacture and testing. Unless otherwise approved, every coupling is to be tested at the makers' works, the tests to include:—

Temperature rise test

High voltage test

Insulation resistance is to be recorded, together with the temperature at which it was measured.

Section 5

DISTRIBUTION

Final Sub-Circuits

501 A final sub-circuit of rating exceeding 15A is not to supply more than one point. The number of lighting points supplied by a final sub-circuit of rating 15A or less is not to exceed:—

for	24— 55 V	circuits	10
,,	110—127 V	,,	14
,,	220—250 V	,,	18

except that in final sub-circuits for cornice lighting, panel lighting and electric signs where lampholders are closely grouped the number of points supplied is unrestricted provided the maximum operating current in the sub-circuit does not exceed 10A.

502 A separate final sub-circuit is to be provided for every motor required for essential services.

503 Lighting circuits are to be supplied by final sub-circuits separate from those for heating and power. (This does not apply to cabin fans and wardrobe heaters).

504 Lighting of cargo spaces and coal bunkers is to be controlled by multi-pole linked switches situated outside these spaces. Provision is to be made for the complete isolation of these circuits and locking in the off position of the means of control.

Navigation Lights

505 Navigation lights are to be connected separately to a distribution board reserved for this purpose only, and connected directly or through transformers to the main or emergency switchboard. The distribution board is to be accessible to the officer of the watch.

Each navigation light is to be controlled and protected in each insulated pole by a switch and fuse or circuit-breaker mounted on the distribution board.

Where the navigation panel is situated in the midships house, the midships sub-switchboard is regarded as an extension of the main switchboard providing it is supplied from the main switchboard by two cables each capable of carrying full load.

Each navigation light is to be provided with an automatic indicator giving aural and/or visual indication of failure of the light. If an aural device alone is fitted it is to be connected to a primary or secondary battery. If a visual signal is used connected in series with the navigation light means are to be provided to prevent extinction of the navigation light due to failure of the signal. The requirements of this paragraph do not apply to tugs, trawlers, fishing and similar small vessels.

Provision is to be made on the bridge for such navigation lights to be transferred to an alternative circuit.

Any statutory requirements of the country of registration are to be complied with and may be accepted as an alternative to the above.

Steering Gear

506 (*a*) Only short-circuit protection and overload alarm are to be provided in steering gear circuits.

(*b*) Indicators for running indication of steering gear motors are to be installed.

The exact position of the rudder, if power operated, is to be indicated at the principal steering station.

(*c*) In all passenger ships and in cargo ships of 5000T gross tonnage and upwards electric and electro-hydraulic steering gear is to be served by two circuits fed from the main switchboard. One of the circuits may pass through the emergency switchboard. Each circuit is to have adequate capacity for supplying all the motors which are normally connected to it and which operate simultaneously.

If transfer arrangements are fitted in the steering gear room to permit either circuit to supply any motor or combination of motors, the capacity of each circuit is to be adequate for the most severe load conditions.

The circuits are to be separated throughout their length as widely as is practicable.

(*d*) In cargo ships of less than 5000T gross tonnage where electric power is the sole source of power for both main and auxiliary steering gear the supply arrangements are to comply with (*c*) above.

If the auxiliary steering gear is powered by a motor primarily intended for other services alternative protective arrangements to that required by sub-para. (*a*) will be specially considered.

(*e*) Where electric control of the steering system is fitted an alternative control system is to be installed. This may be a duplicate electrical control system or control by other means.

Fire Detection, Alarm and Extinguishing Systems

507 (*a*) Where electrically driven emergency fire pumps are installed in accordance with F 403 and F 505, the supply to such pumps is not to pass through the main machinery spaces.

(*b*) Any fire alarm system is to operate both audible and visual signals at the fire detection control station(s). Detection systems for cargo spaces need not have audible alarms.

(*c*) Electrical equipment used in operating fire detecting equipment is to have two sources of electrical power, one of which is to be the emergency source. (*See* M 111 and F 105 with Footnote.)

In addition, the following apply to passenger ships:—

(*d*) Where automatic sprinkler systems are fitted and electrical power is used for the operation of sea water pumps, air compressors and alarms fitted in conjunction with such systems at least two sources of power are to be arranged. The sources of power are to be a main generator and the emergency source of power. (*See* M 111.) One supply is to be taken from the main switchboard by separate feeders reserved solely for this purpose. Such feeders are to be run to a change-over switch situated near the sprinkler unit and the switch is to be normally closed to the feeder from the emergency switchboard. The change-over switch is to be clearly labelled and no other switch other than those at the switchboard(s) is permitted in these feeders.

In passenger ships with aluminium superstructures where feeders from the emergency generator to the sprinkler unit pass through any space constituting a fire risk the cables are to be of fireproof type.

Heating and Cooking

508 Each item of heating or cooking equipment is to be controlled as a complete unit by a multi-pole linked switch mounted in the vicinity of the equipment. In the case of cabin heaters a single pole switch will be acceptable.

Shore Supply

509 (*a*) Where arrangements are made for the supply of electricity from a source on shore or elsewhere a suitable connection box is to be installed in a position in the ship suitable for the convenient reception of flexible cables from the external source and containing a circuit-breaker or isolating switch and fuses and terminals of ample size and suitable shape to facilitate a satisfactory connection. Suitable cables, permanently fixed, are to be provided, connecting the terminals to a linked switch and/or a circuit-breaker at the main switchboard.

(*b*) For three-phase shore supplies with earthed neutral an earth terminal is to be provided for connecting the hull to the shore earth.

(*c*) The shore connection is to be provided with an indicator at the main switchboard in order to show when the cable is energised.

(*d*) Means are to be provided for checking the polarity (for direct current) or the phase sequence (for three-phase alternating current) of the incoming supply in relation to the ship's system.

(*e*) At the connection box a notice is to be provided giving full information on the system of supply and the normal voltage (and frequency if alternating current) of the ship's system and the procedure for carrying out the connection.

(*f*) Alternative arrangements may be submitted for consideration.

Submersible Bilge Pumps

510 Motors of permanently installed submersible bilge pumps are to be connected to the emergency switchboard (if fitted).

Cables and their connections to such pumps are to be capable of operating under a head of water equal to their distance below the bulkhead deck. The cables are to be suitable for operation in permanently wet situations, and installed in continuous lengths from above the bulkhead deck to the motor terminals.

Under all circumstances it is to be possible to start the motor of a permanently installed submersible bilge pump from a position above the bulkhead deck.

Section 6

SWITCHBOARDS, SWITCHGEAR AND PROTECTIVE EQUIPMENT

Switchboards

601 (*a*) An unobstructed space is to be left in front of switchboards. Pipes should, as far as possible, not be installed directly above or in front of or behind switchboards. If such placing is unavoidable suitable protection is to be provided in these positions. (*See* E 275).

(*b*) Where necessary the space at the rear of switchboards is to be ample to permit maintenance and in general not less than 0,6 m (24 in) except that this may be reduced to 0,5 m (18 in) in way of stiffeners or frames.

(*c*) For voltages between poles or to earth above 55 V a.c. or 250 V d.c. dead-front switchboards are to be used. Where live parts on a switchboard are adjacent to a gangway an insulated handrail is to be provided and non-conducting mats or gratings are to be fitted at front and rear of the switchboard as necessary.

(*d*) Section and distribution boards are to be suitably enclosed unless they are installed in a cupboard or compartment to which only authorised persons have access, in which case the cupboard may serve as an enclosure.

All enclosures are to be constructed of, or lined with, non-flammable and non-hygroscopic material and are to be of robust construction.

(*e*) All measuring instruments and all apparatus controlling circuits are to be clearly and indelibly labelled for identification purposes. An indelible label is to be permanently secured to, or adjacent to, every fuse and every circuit-breaker and marked with particulars of the full load current of the generator or cable which the fuse or circuit-breaker protects. The labels for rewirable fuses are also to be marked with the appropriate size of fuse element. Where inverse time limit and/or reverse current devices are provided in connection with a circuit-breaker, the appropriate settings of these devices are to be stated on the label. Name-plates are to be of flame-retardant material.

(*f*) In a passenger ship where there is only one main generating station the main switchboard is to be located in the same fire zone. Where there is more than one main generating station it is permissible to have only one main switchboard.

Busbars

602 Busbars and their connections are to be of copper, all connections being made so as to inhibit corrosion. Busbars and their supports are to be so designed as to withstand the mechanical stresses which will arise during short circuits. The maximum permissible temperature rise for bare conductors is 45 degC (81 degF).

Equaliser Connections

603 The current rating of equaliser connections and equaliser switches is to be not less than half the rated full load current of the generator. The current rating of equaliser busbars is to be not less than half the rated full load current of the largest generator in the group.

Instruments for Direct Current Generators

604 (*a*) For generators not operated in parallel at least one voltmeter and one ammeter are to be provided for each generator.

(*b*) For parallel operation one ammeter is to be provided for each generator, and two voltmeters. One voltmeter is to be connected to the busbars and the other is to be capable of measuring the voltage of any generator.

(*c*) For compound wound generators fitted with equaliser connections the ammeter is to be connected to the pole opposite to that connected to the series winding of the generator.

(*d*) For three-wire generators the ammeter is to be located between the equaliser connection and the generator.

(*e*) For three-wire systems supplied by a three-wire generator or by a balancing booster an ammeter is to be connected to each outer pole of each balancing generator and a voltmeter between each pole of the busbars and the middle wire.

Instruments for Alternating Current Generators

605 (*a*) For alternating current generators not operated in parallel each generator is to be provided with at least one voltmeter, one frequency meter and one ammeter with an ammeter switch to enable the current in each phase to be read or an ammeter in each phase and for generators above 50 kVA a wattmeter.

(*b*) For alternating current generators operated in parallel each generator is to be provided with a wattmeter, and an ammeter in each phase conductor or an ammeter with a selector switch to permit the measuring of current in each phase.

For paralleling purposes two voltmeters, two frequency meters and a synchronising device comprising either a synchroscope and lamps, or an equivalent arrangement, are to be provided. One voltmeter and one frequency meter are to be connected to the busbars, the other voltmeter and frequency meter are to be switched to enable the voltage and frequency of any generator to be measured.

Instrument Scales

606 (*a*) The upper limit of the scale of every voltmeter is to be approximately 120 per cent of the normal voltage of the circuit and the normal voltage is to be clearly indicated.

(*b*) The upper limit of the scale of every ammeter is to be approximately 130 per cent of the normal rating of the circuit in which it is installed. Normal full load is to be clearly indicated.

(*c*) Ammeters for use with direct current generators and kW meters for use with alternating current generators which may be operated in parallel are to be capable of indicating 15 per cent reverse current or power respectively.

Instrument Transformers

607 The secondary windings of instrument transformers are to be earthed.

Earth Indication

608 Every insulated distribution system is to be provided with lamps or other means to indicate the state of insulation from earth.

Protection

609 Installations are to be protected against accidental overcurrents including short-circuit. The protective devices are to provide complete and co-ordinated protection to ensure:—

(i) Continuity of service under fault conditions through discriminative action of the protective devices.

(ii) Elimination of the fault so as to reduce damage to the system and hazard of fire.

Protection against Overload

610 Circuit-breakers and automatic switches provided for overload protection are to have tripping characteristics appropriate to the system. Fuses above 320A are not to be used for overload protection, but may be used for short-circuit protection.

Over-current releases of circuit-breakers for generators and for circuits with preference tripping are to be adjustable.

NOTE.—Overload is considered to be an over-current in a circuit in which the insulation is still effective. Short-circuit is considered to be an over-current in a circuit in which the insulation is defective.

Protection against Short-Circuit

611 Protection against short-circuit currents is to be provided by circuit-breakers or fuses.

The breaking capacity of every protective device is to be not less than the maximum value of the short-circuit current which can flow at the point of installation at the instant of contact separation.

The making capacity of every circuit-breaker or switch intended to be capable of being closed, if necessary, on short circuit, is to be not less than the maximum value of the short-circuit current at the point of installation. On alternating current this maximum value corresponds to the peak value allowing for maximum asymmetry.

Every protective device or contactor not intended for short-circuit interruption is to be adequate for the maximum short-circuit current which can occur at the point of installation having regard to the time required for the short-circuit to be removed.

In the absence of precise data the following short-circuit currents at the machine terminals are to be assumed:—

D.C. SYSTEMS

Ten times full load current for generators normally connected (including spare).

Six times full load current for motors simultaneously in service.

A.C. SYSTEMS

Ten times full load current for generators normally connected (including spare)—symmetrical RMS.

Three times full load current for motors simultaneously in service.

Combined Circuit-Breakers and Fuses

612 The use of a circuit-breaker of breaking capacity less than the prospective short-circuit current at the point of installation is permitted provided that it is preceded on the generator side by fuses, or by a circuit-breaker having at least the necessary breaking capacity. The generator breakers are not to be used for this purpose.

Fused circuit-breakers with fuses connected to the load side may be used where operation of the circuit-breaker and fuses is co-ordinated.

The characteristics of the arrangement shall be such that:—

(i) When the short-circuit current is broken the circuit-breaker on the load side shall not be damaged and is to be capable of further service.

(ii) When the circuit-breaker is closed on the short-circuit current the remainder of the installation shall not be damaged. It is, however, admissible that the circuit-breaker on the load side may require servicing after the fault has been cleared.

Protection of Circuits

613 Short-circuit protection is to be provided in each live pole of a direct-current system and in each phase of an alternating-current system.

Overload protection is to be provided in:—

Two-wire d.c. or single-phase a.c. system—at least one line or phase.

Three-wire d.c. system—both outer lines.

Insulated three-phase a.c. system—at least two phases.

Earthed three-phase a.c. system—all three phases.

No fuse, non-linked switch or non-linked circuit-breaker is to be inserted in an earthed conductor. Any switch or circuit-breaker fitted is to operate simultaneously in the earthed conductor and the insulated conductors.

These requirements do not preclude the provision (for test purposes) of an isolating link to be used only when the other conductors are isolated.

Protection of Generators

614 In addition to over-current protection the following protective gear is to be provided as a minimum:—

(*a*) For generators not arranged to run in parallel: A circuit-breaker arranged to open simultaneously all insulated poles or in the case of generators rated at less than 50 kW a multi-pole-linked switch with a fuse in each insulated pole.

(*b*) For generators arranged to operate in parallel: A circuit-breaker arranged to open simultaneously all insulated poles. This circuit-breaker is to be provided with:—

(i) For direct-current generators, instantaneous reverse-current protection operating at not more than 15 per cent rated current.

(ii) For alternating-current generators a reverse-power protection, with time delay, selected and set within the limits of 2 per cent to 15 per cent of full load to a value fixed in accordance with the characteristics of the prime mover.

The reverse-current protection is to be adequate to deal with the reverse-current conditions emanating from the ship's network, e.g., cargo winches. The reverse-power protection specified for alternating current generators may be replaced by other devices ensuring adequate protection of the prime movers.

(*c*) In addition, the following is to be provided for direct-current generators arranged to operate in parallel.

(i) Where an equaliser connection is in use the reverse-current protection is to be provided in the pole opposite to that in which the series winding is connected.

(ii) For compound generators an equaliser switch for each generator so interlocked that it closes before and opens after the main contacts of the circuit-breaker with which it is associated, or a three-pole circuit-breaker with all poles operating simultaneously.

(iii) In three-wire systems a switch in the connection to the middle wire so interlocked with the generator switch or circuit-breaker connected to the outers as to operate simultaneously with them.

Essential Services

615 Where generators are operated in parallel and essential machinery is electrically driven arrangements are to be made to disconnect automatically the excess non-essential load when the generators are overloaded.

If required this load shedding may be carried out in one or more stages.

Circuits for cargo refrigeration machinery are to be included in the last group to be disconnected.

Power Transformers

616 The primary circuits of power transformers are to be protected against short-circuit by circuit-breakers or fuses.

When transformers are arranged to operate in parallel, means of isolation are to be provided on the secondary windings. Switches and circuit-breakers are to be capable of withstanding surge currents.

Chapter M

Feeder Circuits

617 Isolation and protection of each main distribution circuit is to be ensured by a multi-pole circuit breaker or switch and fuses. Protection is to be in accordance with 610, 611 and 613 except that steering gear circuits are to have short-circuit protection only and overload alarm. The protective devices are to allow excess current to pass during the normal accelerating period of motors.

Circuits which supply motors fitted with overload protection may be provided with short-circuit protection only.

Motors of rating exceeding 0,5 kW/h.p. and all motors for essential services are to be protected individually against overload and short-circuit. The short-circuit protection can be provided by the same protective device for the motor and its supply cable. For essential motors which are duplicated the overload protection may be replaced by an overload alarm if desired by the owner.

For motors intended to provide uninterrupted service the protective gear is to have a delay characteristic to enable the motor to start, yet which will operate on overload before the windings reach an unacceptably high temperature. The current which the protective device will allow to pass indefinitely is not to exceed 125 per cent of the rated current.

For motors for intermittent service the current setting and the delay are to be chosen in relation to the load factor of the motor.

Lighting circuits are to be provided with overload and short-circuit protection.

Meters, Pilot Lamps, Capacitors

618 Protection is to be provided for voltmeters, voltage coils of measuring instruments, earth indicating devices and pilot lamps together with their connecting leads.

A pilot lamp installed as an integral part of another item of equipment need not be individually protected, provided it is fitted in the same enclosure. Where a fault in a pilot lamp would jeopardise the supply to essential equipment such lamps are to be individually protected.

Where capacitors for suppression of radio interference are fitted to busbars, generators, or steering-gear, fuses of appropriate size are to be connected in the capacitor circuit.

Switchgear

619 (*a*) Circuit-breakers and switches are to be of the air break type.

(*b*) The limits of temperature rise are to be based on the cooling air temperatures given in M 1, and when measured by thermometer or thermocouple are not to exceed:—

Contacts:	
Solid copper	40 degC (72 degF)
Silver or similar	65 degC (117 degF)
Bare conductors and connections... ...	45 degC (81 degF)
Coils:	
Class A insulation	50 degC (90 degF)
Class E insulation	65 degC (117 degF)
Class B insulation	80 degC (144 degF)

(*c*) Reports of tests to establish the capacity of circuit-breakers are to be submitted for consideration when required.

(*d*) Each circuit opening device is to be so arranged that when placed in the OFF position it cannot accidentally move so as to close the circuit.

(*e*) Circuit-breakers are to be of the trip-free type.

(*f*) The over-current releases of circuit-breakers for generators and the setting of preference tripping relays are to be adjustable, or if of the non-adjustable type are to be readily replaceable by others of different values.

(*g*) Where reverse-power or reverse-current protection is provided it is to be appropriate to the circumstances of reverse-power between the limits of 2 per cent and 15 per cent of full load that may be expected. (*See* 614(b).)

(*h*) A fall of 50 per cent in the applied voltage shall not render the reverse-current mechanism inoperative although it may alter the amount of reverse-current required to open the breaker.

(*i*) Over-current releases are to be calibrated in amperes, and the settings marked on the circuit-breaker.

(*j*) Handles and operating mechanisms are to be so arranged that the hand of the operator cannot accidentally touch live metal or be injured through an arc arising from the switch or circuit-breaker, or the rupturing of a fuse. If switches are enclosed their handles are not to operate through unprotected slots.

Testing

620 Before installation, switchboards complete or in sections with all components are to pass the following tests at the manufacturers' works and a certificate furnished. A high voltage test is to be carried out on all switching and control apparatus for systems greater than 60 V with a test voltage of 1000 V plus twice the rated voltage (minimum

2000 V) at any frequency between 25 c/s and 100 c/s for one minute applied between (i) all current-carrying parts connected together and earth and (ii) between current-carrying parts of opposite polarity or phase.

For systems of 60 V or less the test shall be at 500 V for one minute.

Immediately after the high voltage test the insulation resistance between (i) all current-carrying parts connected together and earth and (ii) between current-carrying parts of opposite polarity or phase, shall be not less than 1 megohm when tested with a d.c. voltage of at least 500 V.

Instruments and ancillary apparatus may be disconnected during the high voltage test.

Fuses

621 Fuses are to comply with an approved national standard or with the recommendations of the International Electrotechnical Commission and with the following clauses.

The breaking capacity of the fuse is to be not less than the prospective short-circuit current at the point of installation.

Fuses are to be suitable for operating in the ambient temperatures given in M 106 and the temperature rise at the terminals is to be such that the maximum permissible temperature(s) of the connected cable(s) is not exceeded.

622 Fuse-links and fuse-bases are to be marked with particulars of rated current and rated voltage. Each fuse position is to be permanently and indelibly labelled with the current-carrying capacity of the circuit protected by it and with the appropriate approved size of fuse or replaceable element.

623 A list of approved fuses will be issued. To secure approval a report, preferably by an independent authority, is to be submitted giving details of test performance, fusing characteristics, temperature and insulation tests and details of the specification to which the fuse had been tested. Outline drawings are to be included but samples should not be submitted unless requested.

Section 7

CONTROL GEAR

701 The limits of temperature rise for control gear are to be based on the cooling air temperatures given in M 106.

The temperature rise, at full rated load, measured by thermometer or thermocouple is not to exceed:—

Contacts:

Solid copper	60 degC (108 degF)
Silver or similar	75 degC (135 degF)
Bare conductors and connections	45 degC (81 degF)

Coils:

Class A insulation	60 degC (108 degF)
Class E insulation	75 degC (135 degF)
Class B insulation	90 degC (162 degF)

Resistors—maximum operating temperatures shall not exceed 410°C (770°F).

Other parts whether insulated or not are not to reach a temperature which might harm the parts themselves or materials with which they are in contact.

702 Control gear, including isolating and reversing switches is to be so arranged that shunt field circuits are not disconnected without an adequate discharge path being provided.

703 Every electric motor is to be provided with efficient means of starting and stopping so placed as to be easily operated by the person controlling the motor. Every motor above 0,5 kW/h.p. is to be provided with the following control apparatus:

(*a*) Means to prevent undesired restarting after a stoppage due to low volts or complete loss of volts. This does not apply to motors, the continuous availability of which is essential to the safety of the ship.

(*b*) Efficient means of isolation are to be provided so that all voltage may be cut off from the motor and any associated apparatus including any automatic circuit-breaker.

Where the primary means of isolation (that provided at the switchboard, section board or distribution fuse board) is remote from a motor, one of the following is to be provided:—

(i) An additional means of isolation fitted adjacent to the motor.

or (ii) Provision made for locking the primary means of isolation in the OFF position.

or (iii) Provision made so that the fuses in each line can be readily removed and retained by authorised personnel.

(*c*) Means for automatic disconnection of the supply in the event of excess current due to mechanical overloading of the motor (this does not apply to steering motors). (*See also* M 617).

(*d*) Where fuses are used to protect polyphase motor circuits, means are to be provided to protect the motor against unacceptable overload in the case of single phasing.

704 When selecting motor control gear the maximum current of a motor is to be taken as the full load rated current of the motor.

705 Where a single master-starter system (e.g., a starter used for controlling a number of motors successively) is used the apparatus is to provide under-voltage and over-current protection and means of isolation for each motor not less effective than that required for systems using a separate starter for each motor. Where the starter is of the automatic type, suitable alternative means are to be provided for manual operation. Where the starter is used for motors for essential services the starting portion shall be duplicated and means are to be provided for the transfer of the starting duties in the event of failure of one of the starters.

706 Means are to be provided for stopping ventilating fans serving machinery and cargo spaces. These means are to be capable of being operated from outside such spaces in case of fire.

Machinery driving forced and induced draught fans, oil fuel transfer pumps, oil fuel unit pump and other similar fuel pumps are to be fitted with remote controls situated outside the space concerned so that they may be stopped in the event of fire arising in the space in which they are located.

In passenger ships carrying more than 36 passengers all power ventilation systems, except cargo and machinery space ventilation, which is to be in accordance with the first sub-paragraph, are to be fitted with master controls so that all fans may be stopped from either of two separate positions which are to be situated as far apart as practicable.

707 Control gear and resistors are to be tested by the makers with a high voltage applied between the earthed frame and all live parts. The test voltage is to be 1000 V plus twice the rated voltage with a minimum of 2000 V. The voltage is to be alternating at any frequency between 25 and 100 c/s and is to be maintained for one minute without failure.

Immediately after the high voltage test the insulation resistance between (i) all current-carrying parts connected together and earth and (ii) between current-carrying parts of opposite polarity or phase, shall be not less than 1 megohm when tested with a direct current voltage of at least 500 V. Instruments and auxiliary apparatus may be disconnected during the high voltage test.

Section 8

CABLES

Conductors

801 High conductivity annealed copper only is to be used. For rubber-insulated cables the copper wire is to be tinned or alloy coated and the surface is to be bright.

Conductor composition and stranding is to be selected so that adequate flexibility of the finished cable is assured. Conductors of nominal cross section 2,5 mm² (0·003 in²) and less need not be stranded. This requirement does not apply to mineral-insulated cables which have solid conductors. Cores of multi-core cables are to be readily identifiable.

Insulating Materials

802 The following insulating materials are permitted:—

TABLE M 8.1

Insulating Material	Maximum rated conductor Temp. °C	Maximum Ambient Temp. °C
Natural or synthetic rubber (general purpose)	60	50
Polyvinyl chloride compound (general purpose)	60	50
Natural or synthetic rubber (heat resisting)	75	65
Varnished cambric, Butyl ...	80	70
Asbestos-varnished cambric ...	85	75
Silicone rubber	95	—
Mineral...	95	—

NOTE.—Silicone rubber and mineral insulation may be used for higher temperatures when installed where they are not liable to be touched by ship's personnel viz. silicone rubber 150°C mineral unlimited. Proposals to employ these higher temperatures will be specially considered.

Where a rubber or rubber-like material with maximum conductor temperature greater than 60°C is used it is to be readily identifiable.

Other insulating materials will be considered.

Insulation

803 (*a*) Rubber—The use of a single layer is permitted only when applied by the extrusion process. With other processes the insulation is to consist of at least two layers of rubber compound equal or different in quality (including polychloroprene compound but not pure rubber). The layers are to be bonded together.

The insulating wall is to be close fitting, but not adherent to the conductor.

(*b*) Polyvinylchloride—Polyvinylchloride insulation is to be applied by extrusion in one or more layers, is to be close fitting but not adherent to the conductor.

(*c*) Varnished Cambric—Varnished cambric is to consist of a closely woven cloth tape uniformly coated on both sides with an insulating varnish. The average thickness of the finished cloth is to be not less than 0,13 mm (5 mils) nor more than 0,33 mm (13 mils).

The insulating wall is to consist of several layers of varnished-cambric tape, applied helically and smoothly, with or without overlapping, each tape covering the gap, if any of the underlying tape.

An insulating and lubricating compound is to be applied between the layers of varnished cloth so as to exclude air and moisture.

If a binder or identification tape is used and is made of insulating material it may be considered as part of the insulating wall.

(*d*) Asbestos-Varnished Cambric—The insulation of each conductor is to consist of a layer of felted asbestos, impregnated with heat and moisture resisting compound, plus layers of varnished cambric tape plus a layer of impregnated-felted asbestos. In place of felted asbestos, asbestos roving, glass roving, asbestos tape or glass tape may be used.

(*e*) Mineral Insulation—Mineral insulation is to consist of a powdered mineral material, e.g., magnesium oxide, highly compressed between conductors and copper sheath. It is to be temperature-stable and non-corrosive to copper.

Construction

804 Whatever the insulating material used both the belted and non-belted construction may be used for two, three and more conductor cables.

Non-belted Cables

805 For non-belted cables the spaces among the cores are to be filled with fibrous or rubber-like fillers and the cylindrical assembly is to be sheathed with the appropriate protective covering. Fillers may be omitted in multi-core cables having conductor sections 4,5 mm^2 (0·007 in^2) or less.

Belted Cables

806 Belted cables are to be constructed as non-belted cables except that an insulating wall is to be applied to the cabled cores before applying the protective covering. For rubber or PVC-insulated cables the common belt is to be rubber or PVC respectively which may or may not form one body with the fillers.

Fillers

807 When fibrous fillers are used they are to consist of jute or similar rovings (including asbestos, glass, etc.), and are to be resistant to moisture.

When rubber-like fillers are used they are to consist of rubber (including regenerated and/or unvulcanised rubber) compounds or plastic compounds.

Sheaths and Protective Coverings

808 Cables are to be protected by one or more of the following and the sheath or protective covering is to be compatible with the insulation:—

Sheath	Lead-alloy sheath Copper sheath Non-metallic sheath
Protective Covering	Steel-wire armour Steel-tape armour Metal-braid armour (basket weave) Fibrous braid.

Unsheathed cables, e.g., rubber-insulated taped and braided or equivalent may be used only if installed in conduit.

(*a*) Lead-Alloy Sheath—This is to be one of the recommended lead alloys given in I.E.C. Publication 92.

(*b*) Copper—Copper sheath is permitted only for mineral-insulated cables.

(*c*) Metal-Braid Armour (Basket weave)—This is to be formed of galvanised steel, copper or copper alloy or aluminium alloy wires. Aluminium alloy is to be corrosion-resistant. The coverage density of the braid is to be such that the weight of the braid is at least 90 per cent of the weight of a tube of the same metal having an internal diameter equal to the internal diameter of the braid and a thickness equal to the diameter of one of the wires forming the braid.

(*d*) Steel-Wire Armour—This is to consist of galvanized-annealed-steel wires having an elongation at break of at least 12 per cent. The wires are to be applied over the bedding so as to form a uniformly cylindrical layer and so as to ensure adequate flexibility of the cable.

(*e*) Steel-Tape Armour—This is to consist of annealed-steel tape. In general, the armour is to be formed of two tapes wound over the bedding in the same direction so that the gap in the first layer is not more than half the tape width and the second layer covers this gap with an overlap.

Note.—Armour is to be protected against corrosion where necessary. A protective bedding is to be inserted beneath armour (of any type). This may be textile tape or braid, PCP tape or other suitable material. Textile materials are to be treated against moisture.

(*f*) Non-Metallic Sheath—Polychloroprene compound and polyvinylchloride compound may be used for impervious sheaths. For asbestos varnished-cambric cables, asbestos sheath is permissible.

(*g*) Fibrous Braid—Textile braid is to be of cotton, hemp, asbestos, glass, or other equivalent fibre and is to be of strength suitable for the size of the cable. It is to be effectively impregnated with a compound which is resistant to moisture, and flame retarding except where flame-extending cables are permitted by 812.

Dimensions

809 The thickness of insulation and sheath is to be generally in accordance with Tables M 8.2 and M 8.3.

The cables may be used in circuits in which the voltage between a conductor and the hull of the ship does not exceed the voltage at the head of the appropriate Table. In an insulated system the voltage between any conductor and the hull of the ship is assumed to be equal to the voltage between lines.

250 V cables may be used for any conductor of a three-phase, 440 V, alternating-current system with star point earthed.

Cables with other dimensions but which comply with a national specification for marine cables may be submitted for consideration.

Choice of Cables

810 The rated voltage of any cable is to be not lower than the nominal voltage of the circuit for which it is used.

Cables exposed to voltage surges associated with highly inductive circuits, e.g., contactor operating circuits for winches, etc., are to be at least 500 V grade.

The rated operating temperature of the insulating material is to be at least 10degC (18degF) higher than the maximum ambient temperature liable to be produced in the space where the cable is installed.

Where polyvinylchloride insulation is employed, particular care should be taken to avoid damage to the sheathing during the fitting of watertight bulkhead glands.

Choice of Protective Covering

811 Cables fitted in the following locations:—

Decks exposed to the weather
Bathrooms
Cargo holds
Refrigerated spaces
Machinery spaces

or in any other location where water condensation or harmful vapour (e.g., oil vapour) may be present are to have an impervious sheath. In permanently wet situations metallic sheaths are to be used for cables with hygroscopic insulation.

812 All cables are to be of flame-retardant or fire-resisting types (*see* 850) except that flame-extending cables may be used for final circuits only in the following cases:—

(*a*) Where cables are installed in metallic conduits having an internal diameter not exceeding 25 mm (1 in) and provided the conduits are mechanically and electrically continuous.

(*b*) Bare lead sheathed cable having conductor sections not exceeding 4,5 mm^2 (0·007 in^2).

Current Rating

813 The highest continuous load carried by a cable is not to exceed its current rating. The diversity factor of the individual loads and the duration of the maximum demand may be allowed for in estimating the maximum continuous load and is to be shown on plans submitted for approval.

The voltage drop from the main switchboard busbars to any point in the installation when the cables are carrying maximum current under normal conditions of service, is not to exceed 6 per cent of the nominal voltage.

In assessing the current rating of lighting circuits every lampholder is to be assessed at the maximum load likely to be connected to it, with a minimum of 60 watts, unless the fitting is so constructed as to take only a lamp rated at less than 60 watts.

Cables supplying cargo winches, cranes, windlasses and capstans are to be suitably rated for their duty. Unless the duty is such as to require a longer time rating, cables for winch or crane motors may be half hour rated on the basis of the half hour bhp of the motors. Cables for windlass and capstan motors are to be not less than one hour rated on the basis of the one hour bhp of the motor. In all cases the rating is to be subject to the voltage drop being within the specified limits.

TABLE M 8.2

THICKNESS OF INSULATION

Nominal cross section			Rubber and Rubberlike		P.V.C.		Varnished Cambric			Asbestos-Varnished Cambric				Mineral	
			250 V.	660 V.	250 V.	660 V.	1100 V.		3300 V.	250 V.		660 V.		440 V.	660 V.
			Radial	Radial	Radial	Radial	c/c	c/s	c/c; c/s	Radial Cambric	Radial Asbestos	Radial Cambric	Radial Asbestos	c/c; c/s	c/c; c/s
	in.²	mm²	in. *mm*	in. *mm*	in. *mm*	in. *mm*	in. *mm*	in. *mm*	in. *mm*	in. *mm*	in. *mm*	in. *mm*	in. *mm*	in. *mm*	in. *mm*
1/·044	·0015		·030	·055	·025	·035				·018	·020	·030	·030	·040	·060
		1	*0,8*	*1,4*	*0,6*	*0,9*				*0,45*	*0,5*	*0,8*	*0,8*	*1,0*	*1,5*
3/·029	·002		·030	·055	·025	·035				·018	·020	·030	·030	·040	·060
		1,5	*0,8*	*1,4*	*0,6*	*0,9*				*0,45*	*0,5*	*0,8*	*0,8*	*1,0*	*1,5*
3/·036; 1/·064	·003		·030	·055	·025	·035				·018	·020	·030	·030	·040	·060
		2,5	*0,8*	*1,4*	*0,6*	*0,9*				*0,45*	*0,5*	*0,8*	*0,8*	*1,0*	*1,5*
7/·029	·0045		·030	·055	·025	·035	·070	·055		·018	·020	·030	·030	·040	·060
		4	*0,9*	*1,5*	*0,6*	*1,0*	*1,8*	*1,4*		*0,45*	*0,5*	*0,8*	*0,8*	*1,0*	*1,5*
7/·036	·007		·035	·060	·030	·040	·070	·055		·018	·020	·030	·030	·040	·060
		6	*0,9*	*1,5*	*0,8*	*1,0*	*1,8*	*1,4*		*0,45*	*0,5*	*0,8*	*0,8*		*1,5*
7/·044	·01		·035	·060	·030	·040	·070	·055		·018	·020	·030	·030		·060
7/·052	·0145		·040	·060	·035	·040	·070	·055	·130	·018	·020	·030	·030		·060
		10	*1,0*	*1,5*	*0,9*	*1,0*	*1,8*	*1,4*	*3,3*	*0,45*	*0,5*	*0,8*	*0,8*		*1,5*
7/·064	·0225		·040	·060	·035	·040	·070	·055	·130	·018	·020	·030	·030		·060
		16	*1,0*	*1,5*	*0,9*	*1,1*	*1,8*	*1,4*	*3,3*	*0,45*	*0,5*	*0,8*	*0,8*		*1,5*
19/·044	·03		·045	·060	·040	·045	·070	·055	·130	·018	·020	·030	·030		·060
		25	*1,2*	*1,6*	*1,0*	*1,3*	*1,8*	*1,4*	*3,3*	*0,45*	*0,5*	*0,8*	*0,8*		*1,5*
19/·052	·04		·050	·065	·045	·050	·070	·055	·130	·018	·025	·030	·030		·060
		35	*1,4*	*1,6*		*1,3*	*1,8*	*1,4*	*3,3*	*0,45*	*0,6*	*0,8*	*1,2*		*1,5*
19/·064	·06		·055	·065		·050	·070	·055	·130	·018	·025	·030	·045		·060
		50		*1,7*		*1,4*	*1,8*	*1,4*	*3,3*			*0,8*	*1,2*		*1,5*
		60		*1,7*		*1,4*	*1,8*	*1,4*	*3,3*			*0,8*	*1,2*		*1,5*
19/·083	·1			·070		·055	·070	·055	·130			·030	·045		·060
		70		*1,8*		*1,4*	*1,8*	*1,4*	*3,3*			*0,8*	*1,2*		*1,5*
		95		*2,0*		*1,5*	*1,8*	*1,4*	*3,3*			*0,8*	*1,2*		*1,5*
37/·072	·15			·080		·060	·070	·055	·130			·030	·045		·060
		120		*2,3*		*1,6*	*1,8*	*1,4*	*3,3*			*0,8*	*1,9*		*1,5*
37/·083	·2			·090		·065	·070	·055	·130			·030	·075		·060
		150		*2,4*		*1,6*	*1,8*	*1,4*	*3,3*			*0,8*	*1,9*		*1,5*
37/·093	·25			·095		·070	·070	·055	·130			·030	·075		·060
		185		*2,5*		*1,9*	*1,8*	*1,4*	*3,3*			*0,8*	*1,9*		*1,5*
37/·103	·3			·100		·075	·070	·055	·130			·030	·075		·060
		240		*2,7*		*2,0*	*1,9*	*1,5*	*3,3*			*0,8*	*1,9*		*1,5*
61/·093	·4			·110		·085	·080	·065	·130			·030	·075		·060
		300		*3,0*		*2,4*	*2,0*	*1,6*	*3,3*			*0,8*	*1,9*		*1,5*
61/·103	·5			·120		·095	·080	·065	·130			·030	·075		·060
		400		*3,2*		*2,5*	*2,0*	*2,0*	*3,3*			*0,8*	*1,9*		*1,5*
91/·103	·75			·130		·105	·090	·080	·130			·030	·075		·060
		500		*3,3*		*2,7*	*2,3*	*2,0*	*3,3*			*0,8*	*1,9*		*1,5*
		625		*3,5*		*2,8*	*2,5*	*2,3*	*3,3*			*0,8*	*1,9*		*1,5*
127/·103	1·0			·140		·110	·100	·090	·130			·030	·075		·060

c/c = between conductors c/s = between conductor and sheath.

NOTE.—Rubber, Rubberlike and P.V.C. thicknesses are the average of a number of measurements.
Tolerance on declared values :— Rubber and Rubberlike 5%+ 0,13 mm (0·005 in) P.V.C. up to 1,3 mm (0·050 in) 5%+0,076 mm (0·003 in).

TABLE M 8.3

THICKNESS OF SHEATH

Diameter under Sheath		Thickness of Sheath (Average)		
Above	Up to and including	Rubber or P.C.P.	P.V.C.	Lead Alloy
in. *mm*	in. *mm*	in. *mm*	in. *mm*	in. *mm*
	·25 *6,0*	·040 *1,0*	·035 *0,9*	·040 *1,0*
·25 *6,0*	·5 *12,0*	·050 *1,3*	·045 *1,15*	·045 *1,15*
·5 *12,0*	·75 *19,0*	·060 *1,5*	·055 *1,4*	·055 *1,4*
·75 *19,0*	1·0 *25,0*	·070 *1,8*	·070 *1,8*	·065 *1,65*
1·0 *25,0*	1·25 *31,0*	·080 *2,0*	·080 *2,0*	·075 *1,9*
1·25 *31,0*	1·5 *38,0*	·090 *2,3*	·090 *2,3*	·085 *2,15*
1·5 *38,0*	1·75 *44,0*	·100 *2,5*	·100 *2,5*	·095 *2,4*
1·75 *44,0*	2·0 *51,0*	·110 *2,8*	·110 *2,8*	·105 *2,65*
2·0 *51,0*	2·25 *57,0*	·120 *3,0*	·120 *3,0*	·115 *2,9*
2·25 *57,0*	2·5 *63,0*	·130 *3,3*	·130 *3,3*	·125 *3,15*
2·5 *63,0*	2·75 *70,0*	·140 *3,5*	·140 *3,5*	·135 *3,4*
2·75 *70,0*	3·0 *76,0*	·150 *3,8*	·150 *3,8*	·145 *3,7*
3·0 *76,0*	3·25 *82,0*	·160 *4,0*	·160 *4,0*	·155 *3,9*

Tolerances on declared values:—

P.C.P.	5%+0,25 mm (0·010 in)
P.V.C. Up to and including 1,9 mm (0·075 in)	5%+0,18 mm (0·007 in)
Above 1,9 mm (0·075 in)	5%+0,25 mm (0·010 in)
Lead Alloy	5%+0,13 mm (0·005 in)

For lead-alloy sheath, if the minimum at a point method of measurement is preferred the thickness of sheath is to be at least the values given above reduced by 0,25 mm (0·010 in)

The following Table M 8.4 gives the maximum permissible continuous-current rating for single- and multi-core cables, except that where a more precise evaluation of current rating has been carried out based on experimental or calculated data, details may be submitted for approval.

Correction Factors for Current Rating

814 (*a*) Bunching of Cables—Where more than six cables belonging to the same circuit are bunched together a correction factor of 0,85 is to be applied.

(*b*) Ambient Temperature—When it is known that the ambient temperature is different from that given in M 106 the correction factors, as shown in Table M 8.5, are to be applied.

(*c*) Intermittent Service—Where the load is intermittent the correction factors in Table M 8.6 may be applied for half hour and one hour ratings. In no case is a shorter rating than one half hour rating to be used, whatever the degree of intermittency.

Installation of Cables

815 Cable runs are to be, as far as possible, straight and accessible.

816 The installation of cables across expansion joints in the ship's structure is to be avoided. Where this is not practicable a loop of cable of length proportional to the expansion of the joint is to be provided. The internal radius of the loop is to be at least 12 times the external diameter of the cable.

817 Where a duplicate supply is required the two cables are to follow different routes which are to be as far apart as practicable.

818 Cables having insulating materials with different maximum-rated conductor temperatures are not to be bunched together, or, where this is not practicable, the cables are to be operated so that no cable reaches a temperature higher than that permitted for the lowest temperature-rated cable in the group.

819 Cables having a protective covering which may damage the covering of other cables are not to be bunched with those other cables.

820 When installing cables the minimum internal radius of bend is to be generally in accordance with:—

6 d for rubber and PVC cables with metal covering

6 d for rubber and PVC cables exceeding 25,4 mm (1 in) diameter and without metal covering

4 d for rubber and PVC cables exceeding 9,5 mm (0·375 in) diameter and without metal covering

8 d for varnished-cambric cables

4 d for mineral-insulated cables

(d = overall diameter of cable)

Mechanical Protection

821 Cables exposed to risk of mechanical damage are to be protected by metal channels or casing or enclosed in steel conduit unless the protective covering (e.g., armour or sheath) is sufficient to withstand the possible damage.

CURRENT RATING IN AMPERES

(Based on ambient temperature 45°C)

TABLE M 8.4 (a)—GENERAL PURPOSE RUBBER AND P.V.C.

Nominal cross section			Single core	2 core	3 or 4 core
	in²	mm²			
1/·044	·0015		9	7	6
		1	9	7	6
3/·029	·002		11	9	7
		1,5	12	10	8
3/·036; 1/·064	·003		14	11	9
		2,5	17	14	11
7/·029	·0045		18	16	13
		4	23	19	16
7/·036	·007		25	21	17
		6	30	25	21
7/·044	·01		31	26	22
7/·052	·0145		37	31	26
		10	41	34	28
7/·064	·0225		51	43	35
		16	54	45	37
19/·044	·03		60	51	42
		25	70	59	49
19/·052	·04		72	61	50
		35	86	73	60
19/·064	·06		92	78	64
		50	105	91	75
		60	120	100	84
19/·083	·1		125	105	87
		70	130	110	91
		95	160	135	110
37/·072	·15		160	135	110
		120	180	155	130
37/·083	·2		190	160	135
		150	210	180	145
37/·093	·25		220	185	155
		185	240	205	170
37/·103	·3		250	210	175
		240	280	240	200
61/·093	·4		300	255	210
		300	325	275	225
61/·103	·5		D.C. 340 A.C.	D.C. 290 A.C.	D.C. 240 A.C.
	·6		380 375	325 320	265 265
		400	390 385	330 325	275 270
91/·103	·75		445 420	375 360	310 295
		500	450 430	380 365	315 300
		625	520 470	440 375	360 330
127/·103	1·0		530 480	450 405	370 335

TABLE M 8.4 (b)—HEAT RESISTING RUBBER

Nominal cross section			Single core	2 core	3 or 4 core
	in²	mm²			
1/·044 3/·029	·0015 ·002	1	14 14 17	11 11 14	9 9 11
3/·036; 1/·064	·003	1,5 2,5	19 21 25	16 17 21	13 14 17
7/·029 7/·036	·0045 ·007	4	27 32 35	23 27 29	18 22 24
7/·044 7/·052	·01 ·0145	6	42 44 55	35 37 46	29 30 38
7/·064	·0225	10 16	58 74 78	49 62 66	40 51 54
19/·044 19/·052	·03 ·04	25	87 100 105	74 86 89	61 71 73
19/·064	·06	35 50	125 135 155	105 115 135	88 94 110
19/·083	·1	60 70	175 185 195	150 155 165	125 130 135
37/·072	·15	95 120	235 235 270	200 200 230	160 165 190
37/·083 37/·093	·2 ·25	150	285 310 325	240 265 275	200 215 225
37/·103	·3	185 240	355 365 415	300 310 355	250 255 290
61/·093 61/·103	·4 ·5	300	435 480 D.C. 500 A.C.	370 410 D.C. 425 A.C.	305 335 D.C. 350 A.C.
91/·103	·6 ·75	400	560 550 570 560 640 610	475 465 485 475 540 520	390 385 400 390 450 425
127/·103	1·0	500 625	650 620 740 670 760 690	550 530 630 570 650 580	455 435 520 470 530 480

TABLE M 8.4 (c)—VARNISHED CAMBRIC, BUTYL

Nominal cross section			Single core	2 core	3 or 4 core
	in²	mm²			
1/·044	·0015		15	12	10
		1	15	12	10
3/·029	·002		19	16	13
		1,5	21	17	14
3/·036; 1/·064	·003		23	19	16
		2,5	27	22	18
7/·029	·0045		29	24	20
		4	35	29	24
7/·036	·007		38	32	26
		6	45	38	31
7/·044	·01		48	40	33
7/·052	·0145		60	51	42
		10	63	53	44
7/·064	·0225		78	66	54
		16	83	70	58
19/·044	·03		93	79	65
		25	110	93	77
19/·052	·04		115	96	79
		35	135	115	94
19/·064	·06		145	120	100
		50	170	145	115
		60	185	160	130
19/·083	·1		195	165	135
		70	205	175	145
		95	250	215	175
37/·072	·15		255	215	180
		120	290	245	205
37/·083	·2		300	255	210
		150	335	285	235
37/·093	·25		345	295	240
		185	380	320	265
37/·103	·3		390	330	270
		240	445	380	310
61/·093	·4		465	395	325
		300	510	435	355
61/·103	·5		D.C. 530 A.C.	D.C. 450 A.C.	D.C. 370 A.C.
	·6		600 585	510 495	420 410
		400	610 590	520 500	425 415
91/·103	·75		680 640	580 540	475 450
		500	690 640	590 550	485 450
		625	790 680	680 580	550 480
127/·103	1·0		810 690	690 590	570 485

TABLE M 8.4 (d) ASBESTOS-VARNISHED CAMBRIC

Nominal cross section			Single core		2 core		3 or 4 core	
	in²	mm²						
1/·044 3/·029	·0015 ·002	1	16 16 20		13 13 17		11 11 14	
3/·036; 1/·064	·003	1,5 2,5	22 25 28		18 21 23		15 17 19	
7/·029 7/·036	·0045 ·007	4	31 37 41		26 31 34		22 25 28	
7/·044 7/·052	·01 ·0145	6	48 51 64		40 43 54		33 35 44	
7/·064	·0225	10 16	67 83 89		57 70 75		47 58 62	
19/·044 19/·052	·03 ·04	25	99 115 120		84 99 105		69 82 94	
19/·064	·06	35 50	145 155 180		120 130 155		100 110 125	
19/·083	·1	60 70	200 210 220		170 180 185		140 145 155	
37/·072	·15	95 120	270 270 310		220 230 265		190 190 215	
37/·083 37/·093	·2 ·25	150	320 355 370		270 305 315		225 250 260	
37/·103	·3	185 240	405 415 475		345 355 405		285 290 330	
61/·093 61/·103	·4 ·5	300	495 540 570		425 465 480		350 380 400	
			D.C.	A.C.	D.C.	A.C.	D.C.	A.C.
91/·103	·6 ·75	400	640 650 730	620 630 680	545 550 620	530 540 580	450 455 510	435 440 475
127/·103	1·0	500 625	740 850 870	690 730 740	630 720 740	590 620 630	520 590 610	480 510 520

TABLE M 8.4 (e) SILICONE RUBBER, MINERAL

Nominal cross section			Single core	2 core	3 or 4 core
	in²	mm²			
1/·044	·0015		19	16	13
		1	20	17	14
3/·029	·002		23	19	16
		1,5	25	21	17
3/·036; 1/·064	·003		27	23	18
		2,5	31	26	21
7/·029	·0045		34	29	23
		4	41	35	28
7/·036	·007		44	37	30
		6	53	45	37
7/·044	·01		56	47	39
7/·052	·0145		70	59	49
		10	73	62	51
7/·064	·0225		93	79	65
		16	99	84	69
19/·044	·03		110	93	77
		25	130	110	92
19/·052	·04		135	115	94
		35	165	140	115
19/·064	·06		175	150	125
		50	205	175	145
		60	230	195	160
19/·083	·1		240	205	170
		70	255	215	175
		95	310	265	215
37/·072	·15		315	265	220
		120	360	305	250
37/·083	·2		380	325	265
		150	420	355	290
37/·093	·25		440	375	310
		185	485	410	340
37/·103	·3		500	425	350
		240	570	485	400
61/·093	·4		600	510	420
		300	660	560	460
61/·103	·5		690	590	485

822 Cables in cargo holds and other spaces where there is exceptional risk of mechanical damage are to be suitably protected, even if armoured, unless the steel structure affords adequate protection. (*See also* M 1614.)

823 Metal casings for mechanical protection of cables are to be efficiently protected against corrosion.

TABLE M 8.5

Insulation	Correction Factor for Ambient Temperature			
	40°C (104°F)	45°C (113°F)	50°C (122°F)	55°C (131°F)
Rubber or P.V.C. (general purpose)	1,15	1,00	0,82	—
Rubber (heat-resisting quality)	1,08	1,00	0,91	0,82
Varnished Cambric, Butyl	1,07	1,00	0,93	0,85
Asbestos-Varnished Cambric	1,06	1,00	0,94	0,87
Mineral, Silicone Rubber ...	1,05	1,00	0,95	0,89

Earthing

824 Metal coverings of cables are to be effectively earthed at both ends of the cable, except in final sub-circuits where earthing at the supply end only will be considered adequate. This does not necessarily apply to instrumentation cables where single point earthing may be desirable for technical reasons.

825 The electrical continuity of all metal coverings of cables throughout the length of the cable, particularly at joints and tappings is to be ensured.

826 The lead sheath of lead-sheathed cables is not to be used as the sole means of earthing the non-current carrying parts of items of equipment.

Securing of Cables

827 Cables are to be effectively supported and secured without their coverings being damaged.

828 The distances between supports is to be chosen according to the type of cable, the distances being generally in accordance with Table M 8.7.

829 Supports and accessories are to be robust and are to be of corrosion-resistant material or suitably corrosion inhibited before erection.

TABLE M 8.6

Correction Factor	Half Hour Rating		One Hour Rating	
	With Metallic Sheath	Without Metallic Sheath	With Metallic Sheath	Without Metallic Sheath
1,0	Up to ·03 in² 20 mm²	Up to ·1 in² 75 mm²	Up to ·1 in² 67 mm²	Up to ·3 in² 230 mm²
1,1	·04–·06 in² 21–40 mm²	·15 in² 76–125 mm²	·15–·25 in² 68–170 mm²	·4–·6 in² 231–400 mm²
1,15	·1 in² 41–65 mm²	·2–·25 in² 126–180 mm²	·3–·4 in² 171–290 mm²	·75–1·0 in² 401–600 mm²
1,2	66–95 mm²	·3 in² 181–250 mm²	·5–·6 in² 291–430 mm²	
1,25	·15–·2 in² 96–130 mm²	·4 in² 251–320 mm²	·75–1·0 in² 431–600 mm²	
1,3	·25 in² 131–170 mm²	·5–·6 in² 321–400 mm²		
1,35	·3 in² 171–220 mm²	·75 in² 401–500 mm²		
1,4	·4 in² 221–270 mm²			

TABLE M 8.7

External diameter of Cable		Non-Armoured Cables	Armoured Cables
Exceeding	Not Exceeding		
—	0·3 in (7,6 mm)	8 in (20 cm)	10 in (25 cm)
0·3 in (7,6 mm)	0·5 in (12,7 mm)	10 in (25 cm)	12 in (30 cm)
0·5 in (12,7 mm)	0·75 in (20 mm)	12 in (30 cm)	14 in (35 cm)
0·75 in (20 mm)	1·25 in (30 mm)	14 in (35 cm)	16 in (40 cm)
1·25 in (30 mm)	—	16 in (40 cm)	18 in (45 cm)

Penetration of Bulkheads and Decks

830 Penetration of watertight bulkheads or decks is to be carried out with either individual watertight glands or with packed watertight boxes carrying several cables. However carried out the watertight integrity of the bulkheads or deck is to be maintained. (*See also* 810).

831 Cables passing through decks are to be protected by deck tubes or ducts.

832 Where cables pass through non-watertight bulkheads or structural steel the holes are to be bushed with lead or other approved material. If the steel is 6 mm (0·25 in) thick, adequately rounded edges may be accepted as the equivalent of bushing.

833 Materials used for glands and bushings are to be such that there is no risk of corrosion.

834 Where rectangular holes are cut in bulkheads or structural steel the corners are to be radiused.

Installation in Pipes and Conduits

If installed in pipe or conduit the following rules are to be complied with.

835 Metal conduit systems are to be earthed and are to be mechanically and electrically continuous across joints. Individual short lengths of conduit need not be earthed.

836 The internal radius of bend of pipes and conduit is to be not less than that laid down for cables provided that for pipes exceeding 64 mm (2·5 in) diameter the internal radius of bend is not less than twice the diameter of the pipe.

837 The drawing-in factor (ratio of the sum of the cross-sectional areas of the cables to the internal cross-section area of the pipe) is not to exceed 0,4.

838 Expansion joints are to be provided where necessary.

839 Where necessary, ventilation openings are to be provided at the highest and lowest points so as to permit air circulation and to prevent accumulation of water.

Where cables are laid in trunks the trunks are to be so constructed as not to afford passage for fire from one between deck or compartment to another.

840 High voltage cables, e.g., those used for cold cathode luminous discharge lamps, are not to be installed in metal conduit unless protected by metal sheath or screen.

841 Non-metallic ducting or conduit is to be of flame-retardant material. PVC conduit is not to be used in refrigerated spaces or on open decks, unless specially approved.

Installation in Refrigerated Spaces

842 Cables installed in refrigerated spaces are to have a watertight or impervious sheath and are to be protected against mechanical damage. If an armoured cable is used the armour, unless galvanized, is to be protected against corrosion by a further moisture-resisting covering.

Cables entering a refrigerated space are to pass directly through the walls or lagging and are to be protected by a tube sealed at each end. Alternatively, the cables may be passed through solid door frames the necessary holes being sealed at each end.

Precautions are to be taken to prevent the placing of hooks round the cable as a casual means of suspension.

Where PVC insulated cables are used in refrigerated spaces a low temperature grade is to be used.

Cables for Alternating Current

843 Where it is necessary to use single-core cables for alternating-current circuits rated in excess of 20 A the following rules are to be complied with:—

(*a*) Cables are to be either non-armoured or armoured with non-magnetic material.

(*b*) If installed in pipe or conduit, cables belonging to the same circuit are to be installed in the same conduit, unless the conduit or pipe is of non-magnetic material.

(*c*) Cable clips are to include cables of all phases of a circuit unless the clips are of non-magnetic material.

(*d*) When installing two, three or four single-core cables forming respectively single-phase circuits, three-phase circuits or three-phase and neutral circuits the cables are to be in contact with one another, as far as possible. In any event the distance between adjacent cables is not to be greater than 1 diameter.

(*e*) If single-core cables, of current rating greater than 250 A are run along a steel bulkhead wherever practicable the cables should be spaced away from the steel.

(*f*) Where single core cables of rating exceeding 50 A are used, magnetic material is not to be placed between single-core cables of a group. If these cables pass through steel plates, all cables of the same circuit are to pass through a plate or gland so constructed that there is no magnetic material between the cables and suitable clearance is provided between the cable core and magnetic material. This clearance, wherever practicable, is to be not less than 75 mm (3 in) when the current exceeds 300 A. For currents between 50 A and 300 A the clearance is to be obtained by interpolation.

Cable Ends

844 The ends of all conductors of cross-sectional area greater than 4 mm² (0·0065 in²) are to be fitted with soldering sockets, compression type sockets or mechanical clamps. Corrosive fluxes are not to be used.

Cables having a hygroscopic insulation (e.g., varnished cambric or mineral insulated) are to have their ends sealed against ingress of moisture.

Cables with a supplementary insulating belt beneath the protective sheath are to have additional insulation at those points where the insulation of each core makes or may make contact with earthed metal.

Joints and Branch Circuits

845 If a joint is necessary it is to be carried out so that all conductors are adequately secured, insulated and protected from atmospheric action. Terminals or busbars are to be of dimensions adequate for the cable rating.

Testing

846 The following tests are to be made at the manufacturers' works prior to despatch and may be required to be carried out under the supervision of the Surveyors.

All main cable for electric propelling machinery is to be tested in the presence of the Surveyors. (*See* M 1701.)

High Voltage Test

847 The test is to be carried out on finished cables with either direct-current or single-phase alternating-current at the manufacturers' discretion. The power available in the test equipment is to be sufficient to maintain in the cable the specified test voltage and the charging current. The voltage is to be applied gradually so as to arrive at the specified figure in approximately one minute. The test voltage is to be applied as follows:—

For cables with metallic covering the test voltage is to be applied between conductor(s) and the metallic covering. For cables with non-metallic impervious sheath the voltage is to be applied between conductor(s) and the water in which the cable is to be immersed for at least one hour before the test. For cables having a non-metallic covering which might be impaired if immersed in water, the voltage is to be applied to samples, at least 1 m (40 in) long, the surface being covered with metal foil. In addition, for multi-core cables the voltage is to be applied in turn between each conductor and all other conductors connected together.

The test voltage in all cases is to be applied for 5 minutes, without failure, the value being in accordance with:—

TABLE M 8.8

Rated Voltage of Cable		Test Voltage	
Above	Up to and including	A.C. Volts	D.C. Volts
	250	1500	3000
250	750	2500	5000
750	1100	3000	6000
1100	3300	10 000	20 000
3300	6600	16 000	32 000

NOTE.—For mineral insulated cables having a rated voltage up to and including 440 V the test voltage is to be 2000 V alternating current and for voltages above 440 V the test voltage is to be 3000 V alternating current.

Insulation Resistance

848 Immediately after the high voltage test the insulation resistance is to be measured and recorded, using a direct-current voltage of at least 400 V and the measurement being made after electrification for 1 minute. (*See also* M 2002).

Spark Testing

849 Spark testing may be accepted as an alternative to the high voltage and insulation resistance test for cables with rubber or rubber-like insulation. The test is to be made at the core stage except for single core braided and compounded cables which may be tested at the finished stage.

The core or cable is to withstand the test voltage without failure and the speed at which the cable passes through the electrode is to be such that every point is in contact with the electrode for not less than 0,1 sec. Test voltages are given in Table M 8.9.

Flame-Extending, Flame-Retardant and Fire-Resisting Cables

850 A sample of cable 1,2 m (48 in) long is to be clamped vertically in a three-sided enclosure with open top, of size suitable to contain the cable. A bunsen burner of nominal bore 10 mm (0·375 in) fed with ordinary illuminating gas at normal pressure, giving a flame approximately 125 mm (5 in) long with an inner blue cone approximately 40 mm (1·5 in) long, is to be applied to the cable so that the tip of the blue cone touches the cable at approximately 0,4 m (12 in) from its lower end. The burner is to be held at 45° to the vertical and the flame applied for a time

$$t \text{ (secs)} = 10 + \frac{W}{50}$$

where W = weight of cable sample, in grams.

The application is not to be continuous but in steps of 10 seconds, with 10 seconds interruption between applications.

At the end of this period the burner is to be removed and cables are to be graded as follows:—

(*a*) Flame extending when the flame travels along the whole length of the specimen.

(*b*) Flame retardant when the flame extinguishes before reaching the top of the specimen.

(*c*) Fire resisting when, in addition to (*b*) the specimen is able to withstand after cooling an alternating-current test voltage of twice its rated voltage for 1 minute.

NOTE.—To ensure correct heat in the gas flame a bare copper wire 0,7 mm (0.028 in) diameter and of length 100 mm (4 in) is to be inserted horizontally in the flame and 50 mm (2 in) above the top of the burner, so that the free end of the wire is vertically above the edge of the burner on the side of the burner remote from the supported end of the wire. If the wire takes more than 6 seconds to melt then the flame is not hot enough for the test.

Other tests which are the equivalent of the above may be submitted for consideration.

Quality of Materials

851 The quality of materials is to be in accordance with the recommendations of I.E.C. Publication 92.

Alternative requirements of National Standards will be considered.

Section 9

TRANSFORMERS

901 The following Rules apply to all transformers for general use rated from 1 kVA to 1000 kVA inclusive and suitable for operating over an input voltage range up to 3300 volts line to line.

Transformers outside these limits will be specially considered.

Construction

902 Transformers except those for motor starting are to be double wound.

Liquid Cooled Transformers

903 Proposals for the use of liquid cooled transformers will be specially considered.

Number and Rating of Transformers

904 Where essential services are supplied the number and ratings of transformers are to be sufficient to ensure the operation of essential services even when one transformer is out of service.

TABLE M 8.9

Rated Voltage of Cable V	Conductor Sectional Area		Test Voltage (r.m.s.) kV
	Above	Up to and including	
250	—	$\cdot 0225$ in^2 (16 mm^2)	6
	$\cdot 0225$ in^2 (16 mm^2)	$\cdot 04$ in^2 (25 mm^2)	8
	$\cdot 04$ in^2 (25 mm^2)		10
660	—	$\cdot 04$ in^2 (25 mm^2)	10
	$\cdot 04$ in^2 (25 mm^2)		12

Regulation

905 The inherent regulation at 0,8 power factor is not to exceed 5 per cent.

Regulation of the complete system is to comply with M 813.

Temperature Rise

906 The temperature rise of windings of dry type transformers above the ambient temperatures given in M 106, when measured by resistance, during continuous operation at the maximum rating is not to exceed:—

Class A 50°C
Class E 60°C
Class B 70°C

Proposals to use Class H or Class C insulation will be specially considered.

Short-Circuit

907 All transformers are to be capable of withstanding, without damage, the thermal and mechanical effects of a short-circuit at the terminals of any winding for 2 secs.

Tests

908 The following tests are to be carried out on all transformers at the manufacturers' works, and a certificate of tests issued by the manufacturer.

High Voltage Test

(*a*) The voltage is to be applied to each winding in turn, between the winding under test and the remaining windings, core, frame and tank or casing connected together and to earth.

The test is to be made with 1 kV a.c. plus twice the highest voltage between lines with a minimum of 2,5 kV at any frequency between 25 c/s and 100 c/s and maintained for 1 minute without failure.

Induced High Voltage Test

(*b*) To test between turns, coils and terminals an a.c. voltage is to be applied between the above parts corresponding to twice the voltage appearing between these parts when rated voltage is applied to the terminals. The duration of the test is to be 1 minute for any test frequency up to and including twice the rated frequency.

Insulation Resistance

(*c*) The insulation resistance of each winding in turn to all the other windings, core, frame and tank or casing connected together and to earth is to be measured and recorded together with the temperature of the transformer at the time of the test.

Temperature Rise

(*d*) One transformer of each size and type is to be given a temperature rise test.

Section 10

LIGHTING

1001 Lighting which is essential for the safety and the working of the ship is to comply with the following Rules:—

The voltage of tungsten filament lampholders is not to exceed:—

Bayonet Fitting		
Normal	B 22	250 V
Small (single contact)	B 15s	130 V
Small (double contact)	B 15d	130 V
Screw Fitting		
Goliath	E 40	250 V
Medium	E 27	250 V
Small	E 14	250 V
Miniature	E 10	24 V

Lamps are to be in accordance with the following:—

B 22 up to 200 W
E 27 up to 200 W
E 40 no limit

Lampholders are to be constructed of flame-retarding and non-hygroscopic material. All metal parts are to be of robust construction. Goliath lampholders are to be provided with means for locking the lamp in the holder. The temperature of cable connections is not to exceed the maximum conductor temperature permitted for the cable given in M 802.

Fluorescent Lighting

1002 Fittings, reactors, capacitors and other auxiliaries are not to be mounted on surfaces which are subject to high temperatures. In ships for unrestricted service they are to be capable of operating at the ambient temperatures given in M 106.

Capacitors of 0,5 microfarads and above are to be provided with a means of prompt discharge on disconnection of the supply.

Inductors and high reactance transformers are to be installed as close as practicable to the associated discharge lamp.

1003 Where cold cathode luminous discharge lamps of normal operating voltage above 250 V are used a warning notice calling attention to the voltage is to be displayed at points of access to the lamps and where otherwise necessary.

1004 Emergency lighting is to be fitted in accordance with M 111.

Section 11

ACCESSORIES

Enclosures

1101 Enclosures are to be of metal or of flame-retardant insulating materials.

Inspection and Draw Boxes

1102 If metal conduit systems are used inspection and draw boxes are to be of metal and are to be in rigid electrical and mechanical connection with the conduits.

Socket Outlets and Plugs

1103 Where it is necessary to earth the non-current-carrying parts of portable or transportable equipment an effective means of earthing is to be provided at the socket outlet.

On weather decks, galleys, laundries, machinery spaces and all wet situations, socket outlets and plugs are to be effectively shielded against rain or spray and are to be provided with means of maintaining this quality after removal of the plug.

The temperature rise on the live parts of socket outlets and plugs is not to exceed 30°C. Socket outlets and plugs are to be so constructed that they cannot be readily short circuited whether the plug is in or out, and so that a pin of the plug cannot be made to earth either pole of the socket outlet.

All socket outlets of current rating 15 A or more are to be provided with a switch.

Section 12

HEATING AND COOKING EQUIPMENT

1201 Heaters are to be so constructed, installed and protected that clothing, bedding and other inflammable material cannot come in contact with them in such a manner as to cause risk of fire. There is to be no excessive heating of adjacent bulkheads or decks.

Section 13

BATTERIES

The following Rules apply to permanently installed secondary batteries.

Construction

1301 The cells of all batteries are to be so constructed and secured as to prevent spilling of the electrolyte due to the motion of the ship and to prevent emission of acid or alkaline spray.

Location

1302 Alkaline batteries and lead acid batteries are not to be installed in the same compartment.

Large batteries are to be installed in a space assigned to the batteries only or alternatively in a deck box if such a space is not available.

Engine starter batteries are to be located as close as practicable to the engine(s) served. If such batteries cannot be accommodated in the battery room they are to be installed so that adequate ventilation is ensured.

Lining of Compartments

1303 Where acid is used as the electrolyte a tray of lead, or wood lined with lead is to be provided below the cells. Alternatively, the deck below the cells is to be protected with lead or other acid-resisting material so as effectually to prevent any acid from lodging in contact with the ship's structure.

The interiors of all battery compartments including shelves are to be painted with corrosion-resistant paint.

Equipment

1304 Switches, fuses and other electrical equipment liable to cause an arc are not to be fitted in battery compartments.

Supports

1305 Batteries are to be so arranged that each cell or crate of cells is accessible from the top and at least one side. Cells or crates are to be carried on non-absorbent insulating supports. Similar insulators are to be fitted to prevent any movement of cells arising from the motion of the ship.

Ventilation

1306 Battery compartments are to be ventilated by an independent ventilating system.

Natural ventilation may be employed if ducts can be run directly from the top of the compartment to the open air with no part of the duct more than 45° from the vertical.

If natural ventilation is impracticable mechanical ventilation is to be provided. Interior surfaces of ducts and fans are to be painted with corrosion-resistant paint. Fan motors are not to be located in the air stream.

All openings through the battery compartment bulkheads or decks, other than ventilation openings are to be effectively sealed to reduce the possibility of escape of gas from the battery compartment, into the ship.

Where practicable, battery lockers are to be ventilated similarly to battery compartments.

Deck boxes are to be adequately ventilated and means provided to prevent ingress of water.

Size of Batteries and Charging Facilities

1307 Where batteries are used for starting main engines at least two batteries are to be fitted of such combined size that H 611 is complied with.

Adequate charging facilities are to be provided and where batteries are charged from line voltage, by means of a series resistor, protection against reversal of current is to be provided when the charging voltage is 20 per cent of line voltage or higher.

In d.c. systems means are to be provided to isolate the batteries from the low voltage system when being charged from a higher voltage system.

Protection

1308 Batteries, except starter batteries, are to be protected against short circuit by a fuse in each insulated conductor or a multi-pole circuit-breaker at a position adjacent to the battery compartment.

1309 A permanent notice is to be fitted to all battery compartments prohibiting naked lights and smoking.

Section 14

INTERNAL COMMUNICATIONS

1401 Where a communication circuit takes its supply direct from power or lighting circuits and in other cases where the voltage of supply exceeds 50 V a.c. or 60 V d.c. all equipment is to be in accordance with the Rules for power and lighting circuits.

1402 Cables are to be fitted in a similar manner to cables installed for lighting and power, but are to be segregated from the latter unless either the lighting and power cables or the communication cables are metal sheathed, or non-metallic impervious sheathed.

1403 Communication circuits other than those supplied from primary batteries are to be protected against overload and short circuit.

Passenger Alarms

1404 In all passenger ships, except those engaged on short international voyages, electrically operated alarms, for summoning passengers to muster stations are to be fitted. They are to be operable from the bridge.

Steering Gear

1405 Means of communication are to be fitted to enable orders to be transmitted from the bridge to the alternative steering station required by D 2306.

Section 15

SEMI-CONDUCTOR RECTIFIERS FOR POWER

1501 Rectifier stacks are to be so arranged that they may be removed from equipment without dismantling the complete unit.

1502 Where forced cooling is provided the apparatus is to be so arranged that the rectifier cannot remain loaded unless effective cooling is maintained.

1503 When necessary, means are to be provided to guard against d.c. voltage rise due to regenerated power.

1504 When operated in parallel with other sources of d.c. power load sharing is to be such that under normal conditions overloading of any unit does not occur and the combination of paralleled equipment is stable.

1505 Fungus protection of the mercury type is not to be used in the vicinity of selenium rectifiers.

1506 Monocrystalline rectifiers such as germanium and silicon are to be capable of withstanding the effects of transient over-voltages coming from the ship's network.

Section 16

SPECIAL REQUIREMENTS FOR OIL TANKERS AND SHIPS INTENDED FOR THE CARRIAGE IN BULK OF LIQUID CARGOES HAVING A FLASH POINT OF 65,5°C (150°F) OR LESS

Generation and Distribution

1601 The following generation and distribution systems only are to be used:—

Two-wire insulated for d.c. and single-phase a.c.

Three-wire insulated for three-phase a.c.

1602 No current-carrying part of the distribution system is to be earthed other than through an earth indicating device or capacitors used for radio interference suppression.

Equipment in Dangerous Spaces

1603 No electrical equipment or wiring, other than that certified intrinsically safe in respect of the gases and vapours involved (*see* M 109) is to be installed in any space where flammable or explosive vapour may normally be expected to accumulate such as:—

Cargo oil tanks.

Cofferdams adjoining cargo oil tanks.

Cargo pump rooms.

Enclosed spaces immediately above cargo tank crowns (e.g., between decks).

Enclosed spaces, other than cofferdams, adjacent to, and below, the top of a cargo oil tank.

On open deck within 3 m (10 ft) of any oil tank outlet or vapour outlet.

except as detailed in 1604 to 1609.

1604 In enclosed spaces immediately above cargo tank crowns lighting fittings only are to be installed and they are to be of flameproof type. The switches controlling such fittings are to be double-pole and are to be located in a safe place. Through runs of cable are permitted.

1605 Electrical equipment additional to the lighting fittings referred to in 1604 above may be installed in between deck spaces immediately above cargo tank crowns provided that:—

(*a*) Such equipment is housed in a suitably ventilated compartment having access solely from the deck above, and of which the floor is separated from the cargo oil tanks by a cofferdam, and the boundaries are gastight with respect to the cofferdam and the between deck space.

(*b*) Cables are supported clear of the gastight boundaries of the compartment. Plans showing the construction of the compartment, the electrical apparatus to be housed therein and the provisions for ventilation are to be submitted.

1606 In positions on open deck and within a distance of 3 m (10 ft) from cargo tank hatches, sight ports, tank cleaning openings, ullage openings, sounding pipes, cargo vapour outlets or ventilators, or cargo pump room entrances, electrical equipment is to be flameproof.

1607 Hull fittings containing the oscillators of electric sounding devices may be installed in a cofferdam or cargo pump room forward of the oil tanks provided that:—

(*a*) Such fittings are housed in a gastight enclosure clear of the cargo tank bulkhead.

(*b*) The cables to the oscillators are run within the space in heavy gauge galvanized steel pipe with bolted flange joints and led through watertight glands fitted at the external extremity of the pipe.

1608 Cargo pump rooms may be lit by one or both of the following methods:—

(*a*) By flameproof fittings within the compartment. The lamps are to be arranged on at least two independent circuits controlled by fuses and double-pole switches located in a safe space outside the compartment. The lamps and corresponding switches and fuses are to be suitably labelled for identification purposes. Well glasses and other covers are to be secured by screws or nuts requiring a special key for their removal. The cables are to comply with 1613, protected from mechanical damage and supported clear of bulkheads and deckheads.

(*b*) By fittings located in a safe space. Where a safe space is immediately adjacent the cargo pump rooms may be lighted either:—

(i) From that safe space through gastight and watertight glazed ports permanently fitted in the bulkhead or deckhead.

(ii) Or by lighting fittings which are flameproof relative to the cargo pump room and gastight relative to the safe space and so designed to admit replacement of the lamp from the safe space.

1609 Enclosed spaces other than cofferdams adjacent to and below the top of a cargo tank may be lighted in the same manner as cargo pump rooms. The provisions for ventilation are to be submitted for approval. (*See* D 4010.)

Portable Lamps

1610 Portable lamps other than self-contained battery fed or equivalent lamps of a certified type, in respect of the gases and vapours involved, are not to be used in any dangerous space.

Lighting Fittings

1611 Except in accommodation spaces enclosing cases of lighting fittings are to be of metal or equally durable and non-flammable approved material.

Fuses

1612 Only cartridge-type fuses are to be used.

Cables on Fore and Aft Gangways and in Dangerous Spaces

1613 Cables on fore and aft gangways and in dangerous spaces, where permitted, are to be sheathed with one of the following:—

(i) Copper sheath (for mineral insulated cable).

(ii) Lead sheath plus further mechanical protection, e.g. armour or non-metallic impervious sheath.

(iii) Non-metallic impervious sheath plus armour.

Where corrosion may be expected non-metallic impervious sheath, or equivalent protection, is to be applied over steel armour for corrosion protection.

1614 Cables installed on deck in way of cargo tanks or on fore and aft gangways are to be protected against mechanical damage. Where pipes are used the total cross-sectional area of the cables contained within a pipe is not to be more than 30 per cent of the internal cross-sectional area of the pipe. Glands are to be fitted at each bulkhead through which the pipes pass, to allow for expansion and the working of the ship. The pipe system is to be drained and ventilated.

1615 All cables except mineral-insulated copper sheathed cables installed on deck in way of cargo tanks, or on fore and aft gangways and all pipes containing such cables are to be kept throughout their length at such distance from steam and exhaust pipes as to be substantially free from any heating effect from such pipes. At the bulkhead this distance is to be not less than 450 mm (18 in) from the flanges of steam pipes more than 75 mm (3 in) in diameter, and not less than 300 mm (12 in) from the flanges of steam pipes 75 mm (3 in) or less in diameter.

Flameproof Equipment

1616 Where flameproof equipment is required, effective means of complete isolation located in a safe space is to be provided. Effective provision is to be made to prevent unauthorised operation resulting in restoration of supply while the risk of exposing live conductors exists.

Intrinsically Safe Equipment

1617 Where intrinsically safe equipment is installed the wiring of the circuit is to be physically separated from that of other circuits. Intrinsically safe equipment may be used where flameproof equipment is required by the Rules.

Section 17

ELECTRIC PROPELLING MACHINERY

General

1701 All electric propelling machinery including switchgear, control gear, cables, main and auxiliary generators, motors and exciters is to comply with the relevant sections of the Rules and is to be constructed under special survey.

1702 Prime movers are to comply with the relevant sections of Chapter H.

1703 Armature shafts and other important steel forgings and castings are to comply with the requirements of Chapter Q.

1704 The torsional vibration characteristics of the propulsion system are to be submitted as required by H 241 to H 243 as applicable.

1705 Cooling water and lubricating oil systems are to comply with E 8 and E 9 where applicable.

General Arrangements

1706 Where the arrangements permit a propulsion motor to be connected to generating plant having a continuous rating greater than the motor rating, means are to be provided to limit the continuous input to the motor to a value not exceeding the continuous full load torque for which the motor and shafts are approved.

1707 Motors of 500 hp or over and generators of 400 kW or over are to be provided with means for heating the windings to prevent condensation when idle. If steam pipes are used for this purpose the joints are not to be within the machine.

Excitation

1708 Systems dependent on the auxiliary generators for excitation are to be capable of manœuvring and of maintaining power at all times with a fall of 10 per cent excitation voltage at the busbars.

Where motor driven exciters, boosters, balancers or rectifiers are provided for excitation purposes, provision for an alternative supply of excitation is to be made. Where two machines are used each of at least 50 per cent of the required power it will be sufficient to provide one spare machine.

1709 Negative boosters are to be provided with overspeed protection, where necessary.

1710 In d.c. constant pressure systems arrangements for generator and motor excitation are to be such that if the motor excitation circuit is opened by a switch or contactor the generator excitation is simultaneously interrupted or the generator voltage is immediately reduced to zero.

1711 VOLTAGES—No voltage limitations are specified.

Manœuvring Controls

1712 When two or more control stations are provided indicating lights are to be located at each control to indicate which station is in control.

1713 Where bridge or deck control is employed alternative control in the engine room is to be provided.

1714 Suitable interlocks, operating preferably by mechanical means are to be provided to prevent damage to the plant as a result of incorrect switching, such as the opening of switches or contactors not intended to be operated while carrying current.

1715 Provision is to be made for the manual operation without undue manual effort, of all manœuvring contactors, switches, field regulators and controllers. Where electric, pneumatic or hydraulic aid is used for normal operation, failure of such aid is not to result in interruption of power to the propeller shaft and any such device is to be capable of purely manual operation without delay. This latter requirement does not apply to bridge control equipment.

Alternative arrangements will be specially considered.

Cables

1716 Conductors in circuits essential for manœuvring or maintenance of propelling power are to be stranded having not less than seven strands and shall have a nominal cross sectional area of not less than 2,5 mm^2 or $0 \cdot 0045$ in^2.

1717 Cables which are connected to the slip rings of synchronous motors are to be suitably insulated for the voltage to which they are subjected during manœuvring.

1718 All joints are to be so made as to inhibit corrosion. They are to be arranged and supported in a manner suitable for withstanding the electro-mechanical forces due to short-circuit.

Overload and Short-Circuit Protection

1719 Provision is to be made for protection against severe overloads, and electrical faults likely to result in damage to the plant.

Earth Leakage Detection

1720 The main propulsion circuit is to be provided with means for detecting earth faults. For direct-current equipments exceeding 500 V and for all alternating-current equipments, aural and visual alarms are to be automatically operated on the occurrence of an earth fault, but the operation of such devices is not to interrupt the power supply. A switch may be provided to switch off the aural device, but in such cases the visual alarm shall remain switched on to indicate that the aural device is switched off. Alternative arrangements will be specially considered. If an earth connection is used for operating the detector arrangements then in direct-current systems the earth circuit is to be automatically opened in order to stop the circulation of fault current. In alternating-current systems the fault current is to be interrupted or limited to a safe value.

1721 Earth leakage devices are to be arranged to function for all earth faults exceeding 5 amp. In three-phase star connected alternating-current generators and motors with neutral points earthed, the earth leakage device shall operate on the occurrence of an earth fault in the windings of the machine, subject to the provision that 5 per cent of the coils at the neutral end of each phase may be left unprotected by the device. In high voltage a.c. systems where the capacitive leakage current is high consideration will be given to increasing this figure of 5 per cent.

1722 Excitation circuits are to be provided with lamps, voltmeters or other means to indicate continuously the state of the insulation of the excitation circuits under running conditions.

Discharge Protection

1723 For the protection of field windings and cables, means are to be provided for limiting the inducted voltage when the field circuits are opened, or alternatively, the induced voltage, when the field circuits are opened, is to be taken at the nominal design voltage.

1724 Where excitation is obtained from the auxiliary busbars means are to be provided to limit the voltage induced at the busbars when the auxiliary circuit-breaker or the distribution circuit-breaker opens.

1725 Shunt resistors which are connected across the field circuit of synchronous propulsion motors when they are functioning as asynchronous motors are to be suitably insulated for the voltage induced when reversing and are to be amply rated to allow for inadvertent delay during the reversing operation.

Safety Devices

1726 Where separately driven direct-current generators are connected electrically in series means are to be provided to prevent reversal of the direction of rotation of any of them on the failure of the prime mover.

1727 Where, on stopping or reversing the propeller, the regenerated energy transmitted by the propulsion motor is such as to cause a dangerous increase of speed in the prime mover means are to be provided for suitably absorbing or limiting such energy.

1728 Contactors and switches used for reversing the rotation of the propulsion motors are to be provided with means for forcibly opening them if they should inadvertently remain closed and they are to be so interlocked as to prevent the circuits for ahead and astern being closed simultaneously.

Alarms

1729 An aural alarm device is to be provided for machines having enclosed ventilating systems, arranged to operate in the event of the temperature of the heated air exceeding the predetermined safe value.

Identification

1730 All important circuits, instruments and apparatus are to be clearly labelled for identification.

Section 18

SPECIAL REQUIREMENTS FOR HIGH VOLTAGE SYSTEMS (*see* M 203)

NOTE.—High Voltage refers to a marine electrical supply system operating at a voltage in excess of 500 V, 3-phase, a.c.

Introduction

1801 High voltage generation and distribution may be considered appropriate when:—

(*a*) The system fault power under normal operating conditions exceeds 50 MVA.

(*b*) The capacity of individual generating sets is in excess of 2500 kW.

Generation and Distribution

1802 Arrangements are to be made so that it is possible to split the main H.V. switchboard into at least two independent sections, each supplied by at least one generator. The switchboard sections should preferably be located in separate compartments.

1803 The distribution system is to be such that essential services which are duplicated are supplied from separate sections of the switchboard.

Insulated Neutral Systems

1804 For insulated neutral systems special consideration is to be given to the dielectric strength of all high voltage equipment.

1805 In order to preserve the same standard of insulation as with 500 V equipment and to guard against over-voltages which may arise with the insulated neutral system, the test voltage during the high voltage test is to be not less than 7,5 times line to neutral voltage and is to be applied for not less than one minute.

For rotating machinery this extra high voltage test may be replaced by:—

(i) An interturn test on a sample coil.

and (ii) The normal high voltage test carried out on the completed machine (*see* M 428).

The interturn test, between adjacent turns which are not connected in parallel, is to be a type test on the particular insulation system used. The test is to be taken between any adjacent effective turns where the greatest voltage is expected in service. The test is to be made on a coil in the fully processed condition, as it would be in the finished winding and the method of making the test and its duration is to be as in M 428 but preferably at the frequency of the ship's system.

The magnitude of the test withstand voltage is to be as given in Table M 18.1.

TABLE M 18.1

Type of Coil	Interturn Test Voltage
Single stack coils	$\frac{V}{3} + 1000$
Multi stack coils where adjacent conductors in the width stack are connected in parallel	$\frac{V}{3} + 1000$
Multi stack coils with zig-zag series connections	$\frac{2V}{3} + 1000$
Multi stack coils with up/down series connections	$V + 1000$

Where V = System line voltage of the supply for which the coil is designed.

Earthed Neutral Systems

1806 When the earthed neutral system of generation and distribution is used, earthing is to be through a resistor. The resistor is to be such that earth fault current is limited to a value which is not greater than full load current of the largest generator on a switchboard section nor less than three times the minimum current required to operate any device protecting against earth faults.

1807 The high voltage test for equipment in an earthed neutral system is to be as required for medium voltage equipment in other sections of this Chapter.

1808 Generator neutrals may be connected in common provided that the third harmonic content of the waveform of each generator does not exceed 5 per cent.

1809 Where a switchboard is split into sections operated independently or where there are separate switchboards, an earthing resistor is to be provided for each section or for each switchboard.

Means are to be provided to ensure that the earth connection is not removed when generators are isolated.

1810 A means of isolation is to be fitted in the earthing connection of each generator so that generators can be completely isolated for maintenance.

1811 All earthing resistors are to be connected to the hull. In order to eliminate possible interference with radio, radar and communication circuits it is recommended that earthing resistors be bonded together on the hull side of the resistors, and that the means of bonding be separate from that provided by the ship's hull.

Protection

1812 In the earthed neutral system generators are to be provided with protection against internal faults. In the insulated neutral system internal fault protection is recommended.

1813 An efficient means of indicating any earth fault in the system is to be fitted. The indicator may be a low reading ammeter operating from a current transformer in the neutral or leakage indicator or equivalent arrangements ensuring rapid automatic isolation.

1814 Any lower voltage system supplied through transformers from the high voltage system is to be earthed or, alternatively, adequate precautions are to be taken to prevent the low voltage system being charged by leakage from the high voltage system.

Cables, Conductors and Terminations

1815 High voltage cables may be installed:—

(*a*) In the open, e.g. on carrier plating, when they are to be provided with a continuous metallic sheath or armour which is effectively bonded to earth to reduce danger to personnel, or

(*b*) Contained in earthed metallic ducting or pipe when the cables may be as in (*a*) or the armour or metal sheath may be omitted. In the latter case care is to be taken to ensure that ducts or pipes are electrically continuous and that short lengths of cable are not left unprotected. Other cables are not to be run in the same ducts or pipes as high voltage cables.

1816 Where practicable, high voltage cables are not to be run through accommodation spaces.

1817 High voltage cables are to be segregated as far as practicable from cables operating at lower voltages.

1818 All high voltage cables are to be readily identifiable by suitable marking.

1819 When single core cables are used precautions are to be taken against circulating currents in the sheath or armour and the cables are to be transposed at intervals of about 16 m (50 ft).

1820 All high voltage equipment is to be so designed and located that adequate space is provided to ensure efficient cable terminations.

1821 Wherever practicable all conductors are to be effectively covered with suitable insulating material. In terminal boxes if conductors are not insulated, phases are to be separated from earth and from each other by substantial barriers of suitable insulating material.

Switchgear

1822 All circuit-breakers are to be of the fully withdrawable type.

Machines

1823 A lower limit of 200 hp or kW is recommended for 3 kV machines and 400 hp or kW for 6 kV machines.

Section 19

LIGHTNING CONDUCTORS

General

1901 Lightning conductors are to be fitted to each mast of all wood, composite, and steel ships having wooden masts or topmasts. They need not be fitted to steel ships having steel masts.

Construction

1902 In wood and composite ships fitted with wooden masts, the lightning conductors are to be composed of continuous copper tape and/or rope, having a section not less than 100 mm² (0·15 in²) which are to be riveted with copper rivets or fastened with copper clamps to a suitable copper spike not less than 13 mm (0·5 in) in diameter, projecting at least 150 mm (6 in) above the top of the mast. Where tape is used the lower end of the tape is to terminate at the point at which the shrouds leave the mast, and is to be securely clamped to a copper rope of not less than 13 mm (0·5 in) diameter. This copper rope is to be led down the shrouds and is to be securely clamped to a copper plate not less than 0,2 m² (2 ft²) in area, fixed well below the light waterline and attached to the ship's side in such a manner that it is to be immersed under all conditions of heel.

1903 In wood and composite ships fitted with steel masts, each mast is to be connected to a copper plate in accordance with 1902, the copper rope being securely attached to and in good electrical contact with the mast at or above the point at which the shrouds leave the mast.

1904 In steel ships fitted with wooden masts, the lightning conductors are to be composed of copper tape or rope terminating in a spike, as set forth in 1902. At the lower end this copper tape or rope is to be securely clamped to the nearest metal forming part of the hull of the ship.

1905 Lightning conductors are to be run as straight as possible, and sharp bends in the conductors are to be avoided. All clamps used are to be of brass or copper, preferably of the serrated contact type, and efficiently locked. No connection is to be dependent on a soldered joint.

1906 The resistance of the lightning conductor, measured between the mast head and the position on the earth plate or hull to which the lightning conductor is earthed, is not to exceed 0,02 ohms.

Section 20

TRIALS

General

2001 Before a new installation, or any alteration or addition to an existing installation is put into service the following trials are to be carried out. These trials are in addition to any acceptance tests which may have been carried out at the manufacturers' works.

Insulation Resistance

2002 INSTRUMENTS—Insulation resistance is to be measured using a self-contained instrument such as a direct reading ohmmeter of the generator type applying a voltage of at least 500 V.

Where a circuit incorporates capacitors of more than 2 microfarads total capacitance, a constant-voltage type instrument is to be used to ensure accurate test readings.

(*a*) POWER AND LIGHTING CIRCUITS—The insulation resistance between all insulated poles and earth and, where practicable, between poles is to be at least 1 megohm.

The installation may be sub-divided and appliances may be disconnected if initial tests produce results less than this figure.

(*b*) INTERNAL COMMUNICATION CIRCUITS—Circuits operating at 50 V and above are to have an insulation resistance between conductors and between each conductor and earth of at least 1 megohm.

Circuits operating at less than 50 V are to have an insulation resistance of at least 0,33 megohm.

(*c*) SWITCHBOARDS, SECTION BOARDS AND DISTRIBUTION BOARDS—The insulation resistance is to be at least 1 megohm when measured between each busbar and earth and between busbars. This test may be made with all circuit-breakers and switches open and all fuse links for pilot lamps, earth fault-indicating lamps, volt-meters, etc., removed and voltage coils temporarily disconnected, where otherwise damage may result.

(*d*) GENERATORS AND MOTORS—The insulation resistance of generators and motors, in normal working condition and with all parts in place is to be measured and recorded.

The test should be carried out with the machine hot, if possible. The insulation resistance of generator and motor cables, field windings and control gear is to be at least 1 megohm.

Earth Continuity

2003 Tests are to be made to verify that all earth continuity conductors are effective and that the bonding and earthing of metallic conduit and/or sheathing of cables is effective.

Performance

2004 It is to be demonstrated that the Rules have been complied with in respect of:—

Satisfactory commutation and performance of each generator throughout a run at full rated load.

Temperatures of joints, connections, circuit-breakers and fuses.

The operation of engine governors, synchronizing devices, overspeed trips, reverse-current, reverse-power and over-current trips and other safety devices.

Voltage regulation of every generator when full rated load is suddenly thrown off.

For a.c. and d.c. generators, satisfactory parallel operation and kW load sharing of all generators capable of being operated in parallel at all loads up to normal sea or harbour working load. For a.c. generators satisfactory parallel operation and kVA load sharing of all generators capable of being operated in parallel at all loads up to normal sea or harbour working load.

All essential motors and other important equipment are to be operated under service conditions, though not necessarily at full load or simultaneously for a sufficient length of time to demonstrate that they are satisfactory.

Propulsion equipment is to be tested under working conditions and operated in the presence of the Surveyors and to their satisfaction. The equipment is to have sufficient power for going astern to secure proper control of the ship in all normal circumstances. In passenger ships the ability of the machinery to reverse the direction of thrust of the propeller in sufficient time, under normal manœuvring conditions, and so bring the ship to rest from maximum ahead service speed is to be demonstrated at the sea trial.

Voltage Drop

2005 Voltage drop is to be measured, where necessary, to verify that this is not excessive. (*See* M 813.)

Section 21

SPARE GEAR

2101 The following articles of spare gear, so far as they are applicable, are to be carried. Items used are to be replaced or made good by the Owners as opportunity occurs.

2102 One set of brushes and one set of bearings for one machine for each size of generator and for each size of motor engaged on essential services, such as those indicated below:—

Air compressors for heavy oil engines.

Scavenge blowers.

Air pumps.

Ballast pumps.

Bilge pumps.

Circulating and cooling water pumps.

Condenser circulating pumps.

Extraction pumps.

Feed water pumps.

Fire pumps.

Fuel valve cooling pumps.

Lubricating oil pumps.

Oil fuel pumps and oil fuel burning units.

Cargo refrigerating motors, including compressors, brine pump, circulating pump, fans, etc.

Fans for forced draught to boilers.

Steering gear.

Windlasses.

Ventilating fans for engine room and boiler rooms.

Oil separators.

Steering Gear

2103 For each size of steering gear motor and motor-generator if no stand-by electrical machine is installed, the following spare gear is required in addition to the spares for motors enumerated above:—

(i) Direct-current machinery:—

1 spare armature of each size fitted complete with shaft and half coupling.

1 spare field coil of each type fitted.

(ii) Alternating-current machinery:—

1 spare stator complete of each size fitted.

Fans for Refrigerating Equipment

2104 For electrically-driven air circulating fans the following spare gear will be required, in addition to the spares enumerated in 2102 for each size of motor installed, except where a duplicate fan motor in accordance with N 370 is installed:—

1 motor complete, or

Direct-current machinery:—

1 armature complete.

1 complete set of field coils.

1 complete set of brush gear.

1 set of bearings.

Alternating-current machinery:—

1 stator complete.

1 set of bearings.

Control Gear

2105 For the starting gear of motors, such as those enumerated in 2102:—

1 set of contacts which are subject to burning or wear.

1 set of springs.

10 per cent of each different resistance element, but at least one of each.

1 of each type of shunt coil used for contactors, relays or low voltage release.

For six or less starters in which these parts are interchangeable it will be sufficient to provide one set of spares for the starter employing the greatest number of parts.

Switchgear and Distribution Boards

2106 For each type of circuit-breaker on each pole:—

1 set of contacts which are subject to burning or wear.

1 set of parts subject to wear.

1 set of springs.

1 shunt trip coil and 1 resistance element, of each kind used.

15 per cent but not less than six of each type of cartridge or other non-renewable fuses.

Rewireable fuse-handles; 5 per cent, with a minimum of one, of each size or type used, provided that not more than 12 need be supplied.

Navigating and Signal Lights

2107 Navigating and signal lights and their pilot lamps for indicating devices:—

1 complete spare set of lamps.

Emergency Lighting

2108 Where supplied from storage batteries of a voltage different from the ship's circuit:—

1 complete spare set of lamps.

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Electric Couplings

2109 For each size of electric coupling used for propulsion purposes, the following is required as a minimum:—

1 complete set of brush gear.

1 field coil of each type fitted.

1 set of brushes for one coupling.

1 gauge for checking the magnetic air gap.

Spares for the control gear and switchgear as above.

Propulsion Equipment

2110 Owing to the varied characteristics of equipment an exact list of spares cannot be specified but the following should be provided as a minimum:—

(*a*) Generators, Motors and Exciters—One set of bearing bushes, with oil rings, if used, of each size and type for the propulsion generators, motor and exciter.

Two lines of brush holders of each size and type.

One set of carbon brushes for one generator exciter, and one motor.

One shunt field coil of each size and kind used for direct-current generators, exciter and motors.

One set of slip rings for one motor if of the alternating-current type.

(*b*) Switch and Control Gear

One set of contacts liable to burning or wear.

One set of springs.

10 per cent of each different resistance element, but at least one of each.

One of each type of shunt wound coil used for contactors, relays, or trip coils.

Two fuse handles of each type and size, or 15 per cent, but not less than six of each type of fuse.

RECOMMENDATIONS FOR ELECTRICAL EQUIPMENT

The following recommendations are for those features of the electrical installation which are not considered to be the concern of classification and therefore are not included in Chapter M. It should be clearly understood that these recommendations are not mandatory and are intended merely for the use of those Shipowners and Shipbuilders who may seek more guidance on equipment standards than is given in the Rules.

RECOMMENDATIONS FOR ELECTRICAL EQUIPMENT

Section 1

GENERAL

Earthing

Rule 108 The following items do not require to be earthed:—

(i) Lamp caps.

(ii) Shades, reflectors and guards supported on lighting fittings constructed of or shrouded in insulating material.

(iii) Metal parts or screws in, or through, insulating material which are thereby separated from current carrying parts in such a way that they cannot become live or come into contact with earthed parts.

(iv) Portable appliances having double insulation.

(v) Bearing housings which are insulated in order to prevent circulation of current in the bearings.

(vi) Clips for fluorescent lamps.

(vii) Cable clips.

(viii) Apparatus supplied at extra low voltage.

(ix) Fixed apparatus or parts of apparatus which, although not shrouded in insulating material is so guarded that it cannot be touched and cannot come in contact with exposed metal.

Section 2

SYSTEMS OF SUPPLY

It is recommended that in alternating current systems for socket outlets where special precautions against shock are necessary, e.g., portable boiler cleaning tools where the operator works in a confined space and his skin will be damp, the following maximum voltages should be used:—

(i) Supplied direct	55 V
(ii) Where a safety isolating transformer is used supplying only one socket outlet	250 V

Section 4

ROTATING MACHINERY

With the exception of machines for purely domestic purposes such as motors of vacuum cleaners, portable tools and galley equipment it is recommended that all machines comply with the requirements of M 4. Machines for domestic purposes should comply with a national or international standard.

Short Circuit

Sudden short circuit tests, when required by the purchaser, should be a matter for agreement between purchaser and manufacturer. If carried out they should be made at an initial terminal voltage not greater than the rated voltage of the machine and at rated frequency.

Field Regulation of Direct Current Generators

Rule 417 This requirement will be met if at the conclusion of the full load temperature test, with full load current and normal full load voltage at the terminals when running at full load engine speed, the voltage across the shunt field regulator, with an ambient air temperature of 15°C, is not less than 14 per cent of the terminal voltage of the machine. This makes allowance for the difference in field resistance between average test conditions and the most severe service conditions.

Transient Voltage Response of Alternating Current Service Generators

Rule 423 To meet this requirement it is recommended that one of the following alternatives be applied as determined by the characteristics of the installation, but such a test should not be required if evidence can be produced that a test has been carried out on a similar machine.

(*a*) *When the starting kVa of the motors is 35 per cent or less of the capacity of the generating plant and where a rapid voltage recovery is not required.*

With the generator driven at its rated speed at no load and giving its rated voltage under the control of the AVR, the maximum voltage change should not exceed 15 per cent when a current equal to 35 per cent full load current at any power factor between zero and 0,4 lagging is suddenly

drawn. The voltage should be restored to within 3 per cent of rated voltage in not more than 1,5 seconds.

(*b*) *When the starting kVA of the largest motor or group of motors liable to be started simultaneously exceeds 35 per cent but is less than 60 per cent of the capacity of the generating plant.*

With the generator driven at its rated speed at no load and giving its rated voltage under the control of the AVR the maximum voltage change should not exceed 15 per cent when a current equal to 60 per cent full load current at any power factor between zero and 0,4 lagging is suddenly drawn. The voltage should be restored to within 3 per cent of the rated voltage in not more than one second.

(*c*) *When the starting kVA of the largest motor or group of motors liable to be started simultaneously exceeds 60 per cent of the capacity of the generating plant, or when the recovery time of one second is not satisfactory for the operation of special devices supplied by the same generating plant.*

A specification of the performance of the generating plant should be agreed between purchaser and manufacturer.

Wattless Load Sharing

Rule 425. This requirement may be otherwise stated:—

"When alternating current generators are operated in parallel the wattless loads of the individual generating sets should not differ from their proportionate share of the total wattless load by more than 10 per cent of the rated wattless output of the largest machine."

Rule 425 gives a more convenient method of measuring wattless load sharing but other methods can be used, e.g., measurement of the power factor.

Frequency

When running alternating current motors from a shore supply of lower frequency care should be taken to lower the terminal voltage at the motors in proportion to frequency in order not to overload the motors.

Section 5

DISTRIBUTION

It is recommended that in machinery spaces, large galleys and such spaces as corridors, stairways leading to boat decks and public rooms, lighting should be supplied from at least two final sub-circuits one of which could be the emergency circuit so that failure of one circuit does not reduce the lighting to an inadequate level.

Steering Gear

Where electric power is used for the operation of steering gear it is recommended that failure of supply be indicated by audible and visual alarms in the engine room and/or pilot house.

In any steering gear where electric control only is used it is recommended that the control be duplicated.

Section 6

SWITCHBOARDS, SWITCHGEAR AND PROTECTIVE EQUIPMENT

All main and emergency switchboards should be provided with handrails in front of the panel. Where the switchboard is of the open type the rail should be non-conducting. The platform in front of and behind switchboards should have a non-slip surface.

Where necessary insulated handrails should be fitted behind switchboards and passageways behind switchboards should be provided with access doors at each end, these to be capable of being opened from the passageway. The doors should bear a prominent and permanent notice giving the maximum voltage.

For voltages between poles or to earth exceeding 250 V direct current or 55 V alternating current, switchboards should be of the dead front type. Where the voltage exceeds 55 V during operation an insulating mat should be provided.

Where an earth indicating system using either two or three lamps is used the lamps should be of metal filament type each not exceeding 30 W. They should be of the same colour and placed not more than 150 mm (6 in) apart.

For preference tripping systems the following overcurrent settings are recommended (expressed as a percentage of the rated current of the generator or circuit to be protected):—

Main generator circuit breaker	150 per cent
Preference tripping relays	110 per cent

Time delays should be established in accordance with the nature of the load the following values being given as an example:—

First tripping circuit breaker	5 sec.
Second tripping circuit breaker	10 sec.
Third tripping circuit breaker	15 sec.
Main generator circuit breaker	20 sec.

For overloads less than 10 per cent protection may

consist of an alarm signal operated by a time delayed relay set to approximately 110 per cent rated current of the generator.

The two-wire circuits of rating exceeding 100 A should be controlled as a minimum in one insulated pole or phase by a switch. Three-wire alternating current circuits rated at more than 60 A should be controlled by a triple-pole linked switch.

The minimum operating current of every circuit breaker should be not greater than twice the rating of the smallest conductor which it is installed to protect except for motor circuits where short circuit protection only is required (in these cases three times the cable rating).

The overcurrent setting of a circuit breaker will depend on individual arrangements and in motor circuits must be matched to the load temperature characteristics of the motor, the following figures being given merely as an example:—

	Overcurrent
Continuously rated circuits	25 per cent
Intermittently rated circuits	50 per cent
Steering gear and emergency circuits	200 per cent

Circuit breakers, contactors and switches should be so installed that, as far as practicable, their moving parts and associated relays are not live when the circuit breaker or contactor is in the OFF position.

Circuit breakers and contactors should be provided with a means of isolation.

In large installations, where fault levels are high, circuit breakers should be of the power operated type.

In earthed systems of large capacity, protection against internal faults in the generators should be considered.

All generators arranged for parallel operation with one another or with the shore power feeder should be provided with undervoltage release which prevents the closing of the appropriate circuit breaker until the generator terminal voltage reaches at least 70 per cent of the rated voltage.

The installation of automatic circuit opening devices, other than for short circuit protection, is not recommended in exciter circuits.

In alternating current systems consideration should be given to the fitting of an automatic trip to main generator circuit breakers which will open the breaker on loss of excitation.

The fitting of an ammeter in exciter circuits is recommended.

Selection of Fuses

(i) Fuses for steady load circuits, such as heating circuits, should be of current rating at least equal to that of the apparatus. If other overcurrent protection is provided or if discrimination requires it, a fuse of greater current rating may be necessary.

(ii) Fuses for fluctuating load circuits, such as motor circuits, transformer circuits, lighting circuits and capacitor circuits, should have a time/current characteristic which allows the transient overcurrent to be carried without operation of the fuse. It will sometimes be necessary to select fuses of a current rating greater than that of the circuit.

For motor circuits it will be necessary to obtain particulars of the magnitude and duration of the starting current and to select fuses by referring to the time/current characteristics.

Section 8

CABLES

In large installations where short circuit currents may be high it is recommended that cables are armoured and in three-phase installations, as far as is practicable, three-core cables carrying the three-phase currents should be employed.

Where these precautions are necessary particular care should be taken with the cable supports especially at the ends of cables.

In 110 V installations where lighting cables may be fully loaded, are bunched together and are installed between wooden panelling or similar locations it is recommended that the minimum size of conductor be not less than 2,5 mm^2 (0·003 in^2).

Section 10

LIGHTING

In bathrooms, galleys, laundries and similar places the parts of a lampholder likely to be touched should be constructed of or shrouded in insulating material and fitted with a protective shield or totally enclosed fittings should be used.

Lighting switches for bathrooms and similar locations should be outside such spaces unless they are of construction suitable for humid conditions.

Lamps which are used near combustible material should be installed in totally enclosed fittings.

Where tubular fluorescent lighting is used, lighting by one or more filament lamps should be provided, especially in compartments containing running machinery.

Lamps which are used in spaces liable to contain explosive or inflammable materials should be installed in flameproof fittings.

Filament lamps are recommended for emergency lighting.

Live parts of fluorescent lighting installations should be screened with earthed metal or insulating material.

Connections to Lighting Fittings

Due to the reduced physical sizes of lamps in many countries, e.g., 100 W lamps can now be installed in many fittings that previously were designed for 60 W lamps, care must be taken with cable connections so that the maximum conductor temperature is not exceeded. Tests carried out in the past have shown a temperature rise at some lampholder terminals of 80°C and a distance about 16 mm (0·625 in) from the lampholder terminals exhibited a temperature rise of 60°C.

Where cables operate at temperatures in excess of the permitted maximum, deterioration of the insulation occurs with premature failure in service.

Comments on the behaviour of the various classes of insulation are given below:—

(*a*) Rubber

Maximum conductor temperature 60°C. At higher temperatures it ages with increasing severity, reducing its life.

(*b*) Polyvinyl Chloride

Maximum conductor temperature 60°C. At higher temperatures it may flow away from the conductor when under pressure, e.g., clips.

(*c*) Polychloroprene

This is usually associated with rubber when maximum conductor temperature is 60°C. At higher temperatures it absorbs moisture after cooling leading to electrical breakdown.

(*d*) Butyl

Maximum conductor temperature 80°C. At 130°C it ages rapidly and may turn into a powder which can fall away from the conductor if subject to vibration or shock.

(*e*) Silicone Rubber

Maximum conductor temperature 150°C and intermittently up to 200°C.

Fittings should be designed so that the maximum permitted temperature for the cable is not exceeded. Alternatively, high temperature tails (e.g., silicone rubber) should be incorporated in the fitting and led to a terminal block.

Section 11

ACCESSORIES

Where differing distribution systems are used any socket outlets and plugs should be of such design that incorrect connection cannot be made.

In general, socket outlets should not be fitted in bathrooms, lavatories and similar wet places.

In systems at 110 V direct current and above or 55 V alternating current and above socket outlets and plugs should be provided with an earthing contact. This contact should make contact before the live pins when the plug is inserted.

Heating and Cooking Equipment

Electric heating and cooking equipment should be so constructed that parts which must be handled cannot exceed 55°C.

Heating elements should be readily replaceable.

Connections between elements, switches and supply cables should be carried out with terminals.

Connections between elements and between elements and terminals to which insulated cables may be connected, unless self-supporting and rigidly secured in position should be continuously insulated with incombustible material.

Heating elements should be suitably guarded. Live parts of cooking appliances should be protected so that cooking utensils cannot come into contact with them.

Space heaters in cabins, lockers, etc., should be of the convector type. Space heaters should not be installed in spaces where inflammable gases might accumulate.

Batteries

Batteries should be located where they are not exposed to excessive heat or extreme cold. Batteries for emergency service, including emergency diesel engine starting should be located above the bulkhead deck. The best operating conditions for batteries are obtained when the working temperature is between 15°C and 27°C. Where practicable the temperature of the electrolyte should not be permitted to exceed 50°C since higher temperatures tend to reduce the life of the battery. Low temperatures may temporarily reduce the capacity of the battery.

Mechanical ventilation of battery rooms should be capable of changing the air in the battery room four or five times per hour.

Spare Gear

The provision of an insulation tester is recommended.

Section 16

SPECIAL REQUIREMENTS FOR OIL TANKERS

Flameproof and Intrinsically Safe Equipment

It is sometimes stated that flameproof equipment should be permitted in dangerous spaces, e.g., cargo pump rooms, but this cannot be agreed except as stated in M 16. Flameproof equipment is flameproof when it leaves the manufacturers' works and after a period of service may no longer be flameproof, due to faulty or inadequate maintenance.

Flameproof lighting fittings are permitted in pump rooms, only because many pump rooms are so large that they cannot be adequately lit through glazed ports.

Intrinsically safe equipment and the circuit to which it belongs is to be physically separated from all other circuits. This is because the certificate of intrinsic safety involves both the equipment and its circuit.

Chapter N

REFRIGERATED CARGO INSTALLATIONS

Extract from Chapter B for reference

B 901 On application from Owners, refrigerated cargo installations which comply with Chapter N of the Rules and are favourably reported on by the Surveyors will be assigned an appropriate class in accordance with N 1. Certificates will be issued and the class notation, together with the particulars of the installation, will be entered in the Supplement.

B 902 The class assigned will be retained provided the installation is found to be in a good and efficient condition at the Periodical, Loading Port, and other Surveys set forth in N 8.

B 903 The paragraphs in B 14 regarding Withdrawal of Class and in B 15 regarding Reclassification, apply also to Refrigerated Cargo Installations.

Section 1

GENERAL

Class Notation

101 The class notation assigned will be Lloyd's RMC followed by the minimum temperature(s) approved by the Committee for the installation with the maximum sea temperature stated, e.g. "to maintain temp. 10°F. in the lower and 31°F. in the upper chamber with sea temperature 85°F. maximum."

NOTE.—The temperature at which the cargo is to be carried is not the responsibility of the Society.

102 Installations constructed under the Society's Special Survey in accordance with N 2 to N 6 will be eligible for the distinguishing mark ✠ before the class notation, thus ✠Lloyd's RMC. In other cases the mark ✠ will not be assigned.

103 In the case of installations designed to reduce the temperature of non-precooled cargoes a mark ‡ will be shown under the class notation in the Appendix to the Register Book and will be included on the certificate as an indication that an installation has been considered by the Society for this duty. A special statement showing the cargo cooling capabilities of such installations, in respect of stated weights and descriptions of cargoes under stated conditions, will be issued on application by the Owners to the Society's Head Office.

Special Cases

104 The Committee will be prepared to give consideration to cases of ships engaged on voyages of short duration, to installations of small capacity, or to other special circumstances. In such cases the class may include a service limitation or other restriction.

Refrigerants

105 These Rules are applicable to the following primary refrigerants:—

Carbon Dioxide
Ammonia
Dichlorodifluoromethane
Monochlorodifluoromethane

Proposals to use other refrigerants will be specially considered on application, but methyl chloride will not be accepted.

NEW INSTALLATIONS

Section 2

SPECIAL SURVEY DURING CONSTRUCTION

201 New installations intended for classification are to be constructed under the Society's Special Survey in accordance with the requirements of N 3 and N 4; tests are to be carried out as specified in N 5, and spare gear is to be supplied as listed in N 6.

Information and Plans to be Submitted

202 The following information and plans are to be forwarded for consideration before construction is commenced :—

(*a*) Refrigerating plant—standard data sheet in duplicate. (Copies of this data sheet may be obtained from the Society's local office.)

(*b*) Refrigerating plant—detailed specification in triplicate.

(*c*) Insulation—detailed specification in triplicate.

(*d*) General arrangement of insulated chambers in elevation and plan. The plans are to be to a scale adequate for the measurement of the external surfaces and the deck

and bulkhead edges. Dimensions and spacing of frames, beams and stiffeners and details of other steel work protruding into the insulation and within the chambers are to be shown. Oil fuel and liquid cargo tanks adjacent to or below the chambers are to be indicated, and whether heating is provided for such tanks. Ventilating and air conditioning trunks and ducts passing through chambers are to be shown. The plans should include a diagram showing the position of the chambers in relation to other parts of the ship if this is not otherwise apparent.

(*e*) Detailed plans showing the thickness and methods of attachment of the insulation and linings on all surfaces, including girders, hatch coamings and pillars; details of insulated doors, and hatch, access, bilge and manhole plugs and their frames. Method of attachment of brine or direct expansion grids and meat rails are also to be shown.

(*f*) Arrangement of air ducts (including method of cooling spaces within hatch coamings), air coolers, fans and their motors.

(*g*) Air cooler defrosting arrangements, other than hot brine circulating systems.

(*h*) Arrangement of brine grids including those in way of hatches; and method of construction.

(*i*) Arrangement of chamber thermometers.

(*j*) General arrangement of refrigerating machinery.

(*k*) Brine circuit diagram with particulars of piping.

(*l*) Primary refrigerant gas and liquid circuit diagrams and full particulars of all pressure piping.

(*m*) Sectional arrangement of refrigerant compressors.

Detailed dimensioned plans of :—

(*n*) Compressor crank shafts.

(*o*) Compressor crank cases where exposed to the refrigerant pressure.

(*p*) Condensers.

(*q*) Evaporators (brine coolers).

(*r*) Air coolers.

(*s*) Oil separators.

(*t*) Liquid receivers.

(*u*) All other pressure vessels.

NOTE.—All the plans listed, and any others which may be specially requested are to be forwarded in triplicate.

(*v*) Similar plans are required for refrigerating plant of other designs.

(*w*) Where the refrigerating machines are driven by oil engines particulars and plans are to be submitted in accordance with the requirements of G 104.

(*x*) Where the refrigerating machines or air cooler fans are driven by steam engines particulars and plans are to be submitted in accordance with G 104.

(*y*) Where air cooler or necessary air stirring fans are electrically driven plans of the motors are to be submitted in accordance with M 429.

(*z*) Where it is proposed to apply centralised, bridge or automatic controls, a description of the scheme and particulars of the spares to be carried are to be submitted.

Refrigeration required in excess of N 306

203 Refrigeration required in excess of that specified in N 306, which may be necessary for rapid cooling of chambers, or cooling cargoes loaded at temperatures above the carrying temperature, is to be in accordance with a specification approved by the Owners.

Rate of Air Circulation

204 Where refrigeration is effected by forced air circulation over coolers the proposed fan output in each chamber will be considered in relation to the heat to be removed, the nature of the cargo and the service(s) intended.

Where chambers are intended for the additional duties mentioned in 203 the rate of air circulation is to be in accordance with the Owners' requirements.

Subsequent Modifications or Additions

205 Any subsequent modifications or additions to particulars and/or arrangements shown on the approved plans or in the specifications are also to be submitted for approval.

Novel Arrangement and Designs

206 Where the proposed construction of the refrigerating plant or refrigerated chambers is novel in design or involves the use of unusual material, special tests may be required, and a suitable class notation may be assigned when the Committee consider this necessary.

Survey Requirements

207 From the commencement of the construction and installation of the refrigerating plant and of the insulation and fitting out of the cargo chambers, to the testing of the completed installation, the Surveyors are to examine the materials and workmanship and are to indicate at the earliest opportunity and require the rectification of any items not in accordance with the Rules or the approved specifications and plans, or any material, workmanship or arrangement found to be defective or unsatisfactory.

Section 3

REFRIGERATING PLANT

Definition of a Unit

301 A refrigerating unit comprises a prime mover, one or more refrigerating machines (refrigerant gas compressors), one gas condenser—and in the case of a secondary refrigerant, one brine cooler (gas evaporator)—and the fittings necessary to permit independent operation of the unit.

302 If the prime mover of a refrigerating machine is a steam engine with two or more cylinders and each cylinder drives a corresponding compressor, or there is more than one motor similarly arranged, and if each compressor is connected to its own condenser and brine cooler (where fitted), the arrangement is to be regarded as two or more units as the case may be, provided the units can be used separately or in combination.

NOTE.—Condensers or evaporators of the coil-in-casing type need not necessarily be in separate casings.

303 Two or more refrigerating machines (or compressors) driven by a single prime mover, or having only one condenser or one brine cooler (where fitted), are to be regarded as one unit.

304 Where a refrigerating plant is provided for sub-cooling the liquid refrigerant, or cooling the condensers of other refrigerating machines, and is not arranged for cooling the cargo spaces independently, it will not be regarded as a unit.

305 Where a refrigerating plant is dependent on the main refrigerating units for cooling the condenser or the refrigerant liquid, it will not be regarded as a unit.

Refrigeration to be Provided

306 The refrigeration provided is to be capable of efficiently maintaining the minimum temperature(s) under the conditions applicable to the maximum sea temperature for which approval by the Committee is desired and which is to be specified in the class notation (*see* N 101), when working 24 hours a day with any one of the refrigerating units out of action. It is recommended that a reasonable margin in plant output over maximum load be allowed for possible overall inefficiencies under service conditions.

307 Where part of the necessary refrigeration is obtained by the sub-cooling of the liquid refrigerant by other refrigerating plant, one plant supplying such sub-cooling may be considered sufficient provided the refrigerating units including the stand-by unit are capable of the full duty specified in 306 in the event of the sub-cooling plant being out of action.

308 In any case where all the refrigerating units are not connected for use on all the refrigerated cargo chambers the plant serving each chamber is to comply with the requirements of 306.

309 The foregoing requirements are based on the assumption that installations will have relatively few refrigerating units each arranged to serve all chambers. In the case of installations having a large number of small units arranged to serve individual chambers, or groups of chambers, the question of reserve plant will be the subject of special consideration.

Number of Refrigerating Units

310 Not less than two complete refrigerating units are to be fitted. Where two units only are fitted the working parts are to be interchangeable.

Stand-by Pumps

311 A stand-by gas condenser cooling water pump is to be installed ready for use in addition to the pumps required for the full duty specified in 306. This stand-by pump may be one of the pumps used for other purposes provided it is of adequate capacity and its use on the gas condenser does not interfere with other essential services.

312 Where brine is used for refrigerating the cargo chambers a stand-by brine circulating pump is to be installed ready for use in addition to the pumps required for the full duty specified in 306.

Sea Connections

313 Condenser cooling water is to be taken from not less than two sea connections, one of which may be that provided for other purposes, such as the water ballast inlet. It is recommended that one of the sea connections be provided on the port and the other on the starboard side.

Location of Machinery

314 Where ammonia refrigerant is used the refrigerating machinery is to be in an efficiently ventilated compartment isolated from the propelling machinery spaces and shaft tunnels, and living quarters.

Machinery using non-toxic and non-inflammable refrigerants will not be subject to restriction on location in general, but proposals to install relatively large plants in propelling machinery spaces will require special consideration.

Prime Movers

315 Where refrigerating plant is electrically driven the motors and their control gear are to comply with the requirements of M 4 and M 7.

316 Where the refrigerating machinery is steam driven the steam engines are to comply with the requirements of Chapters G and H and the exhaust steam is to be led to the main and auxiliary condensers.

317 Where the refrigerating machinery is driven by oil engines the requirements of Chapters G and H are to be carried out.

Motive Power

318 In the case of 315 the electric power is to be taken from at least two generators (*see also* M 403) and in the case of 316 steam is to be taken from at least two boilers, each capable of the maximum duty without interference with other essential services.

Plant on Ships not classed with the Society

319 In the case of refrigerating installations being constructed under the Society's Special Survey on ships not intended to be classed with this Society, the generator engines and electrical equipment, which supply power to the refrigerating installations, should be constructed in accordance with the requirements of the Classification Society concerned, but such plant is to be examined generally and under working conditions.

Steel Castings

320 Important steel castings are to comply with the requirements of Q 5.

Steel Forgings

321 Crank shafts and other important steel forgings are to comply with the requirements of Q 6.

Dimensions of Crank Shafts

322 Crank shafts of single acting reciprocating refrigerant compressors, of mild steel having a tensile breaking strength of 44–50 kg/mm^2 (28–32 ton/in^2) are to have dimensions not less than those calculated from the following formulæ.

Where crank shafts are proposed to be made of steel of greater strength or of other material, the particulars including the material specification are to be submitted for special consideration.

323 The formulæ are applicable to compressors operating on the normal cycle, with crank shafts having one, two, three or four cranks at equal angles and one cylinder acting on each, and with two or more main bearings.

324 The formulæ are also applicable to compressors, other than CO_2 having the crank and cylinder arrangements as shown in Table N 3.1, but in these cases the calculated shaft diameter is to be increased by 5%, 18% and 25% when the angle between cylinders is 90°, 60° and 45° respectively.

TABLE N 3.1

Number of crank pins	Number of cylinders per crank	Angle between cylinders
1 or 2	2	45°, 60° or 90°
3	2	45° or 60°
4	2	45° or 60°
1	3	45°, 60° or 90°
2	3	45° or 60°
3	3	45°
1	4	45° or 60°
2	4	45°

325 The formulæ are not applicable to crank shafts having more than one crank on the same top centre, or to compressors where the cylinders are arranged for supercharging by gas of higher pressure at an intermediate stage of the stroke.

Diameter of Crank Shafts

326

TABLE N 3.2

Refrigerant	Diameter of crank shaft (All dimensions in mm or in)
Carbon Dioxide (CO_2)	$\sqrt[3]{\dfrac{D^2\left(15\dfrac{ab}{a+b}+1{,}25S\right)}{12}}$ for gas discharge pressures up to 105 kg/cm^2 (1500 lb/in^2)
Ammonia (NH_3) Monochlorodifluoromethane ($CH\,Cl\,F_2$)	$\sqrt[3]{\dfrac{D^2\left(2{,}5\dfrac{ab}{a+b}+0{,}15S\right)}{12}}$ for gas discharge pressures up to 17,5 kg/cm^2 (250 lb/in^2)
Dichlorodifluoromethane ($C\,Cl_2\,F_2$)	$\sqrt[3]{\dfrac{D^2\left(1{,}5\dfrac{ab}{a+b}+0{,}1S\right)}{12}}$ for gas discharge pressures up to 10,5 kg/cm^2 (150 lb/in^2)

where D = cylinder diameter,

S = length of stroke,

a = distance from the inner edge of one bearing to the centre line of the crankpin nearest the centre of the span,

b = distance from the centre line of the same crankpin to the inner edge of the other bearing,

$a + b$ = distance (or span) between the inner edges of adjacent main bearings.

327 Where it is proposed to make solid forged crank shafts of steel having a specified minimum tensile strength greater than 44 kg/mm² (28 ton/in²), but not exceeding 80 kg/mm² (50 ton/in²), the diameter of the crank shaft is not to be less than given by the following formula:—

$$\text{Diameter of crank shaft} = d \times \sqrt[3]{\frac{44}{0{,}72T + 12{,}6}} \text{ mm}$$

$$\left(d \times \sqrt[3]{\frac{28}{0{\cdot}72T + 8}} \text{ in}\right)$$

where d = diameter, in mm (in), of crank shaft made of steel having a specified minimum tensile strength of 44 kg/mm² (28 ton/in²) as required by 326,

T = proposed specified minimum tensile strength in kg/mm² (ton/in²).

Crank Webs

328 Crank webs are to be of the following proportions or of equivalent strength :—

Breadth of web	= 1,33 × calculated shaft diameter
Thickness of web adjacent to a bearing	= 0,56 × calculated shaft diameter
Thickness of intermediate webs	= 0,75 × calculated shaft diameter

CAST IRON CRANK SHAFTS

General

329 Where it is proposed to make crank shafts of cast iron, the material specification and the dimensions of the shaft are to be submitted for special consideration.

Material

330 The material specification should state the type of cast iron, the heat treatment, and mechanical properties, including the specified minimum tensile strength appropriate to the section of the crank shaft casting.

331 Any suitable type of high duty cast iron may be used, provided the minimum specified tensile strength is between 32 and 76 kg/mm² (20 and 48 ton/in²). Crank shafts are to be cast at a foundry approved for the production of cast iron crank shafts. (*See* Q 8).

Crank Shafts

332 The diameter of the crank shaft is not to be less than that given by the following formula:—

$$\text{Diameter of crank shaft} = d \times \sqrt[3]{\frac{22}{0{,}3T + 7{,}9 - \frac{d}{48}}} \text{ mm}$$

$$\left(d \times \sqrt[3]{\frac{14}{0{\cdot}3T + 5 - \frac{d}{3}}} \text{ in}\right)$$

where d = diameter, in mm (in), required by 326 for a steel crank shaft having a tensile strength of 44 kg/mm² (28 ton/in²),

T = specified minimum tensile strength of cast iron in kg/mm² (ton/in²) which is not to be less than 32 kg/mm² (20 ton/in²).

333 Special consideration will be given to crank shafts which have been designed and developed for optimum fatigue strength with cranks of the most favourable shape, and some allowance made for the superior strength thereby obtained. Particulars of any relevant tests or experience should be submitted.

Crank Webs

334 The proportions of the crank webs are to be as stated in 328.

Fillets and Oil Holes

335 Fillets at the junctions of crank webs with crank pins or journals are to be machined to a radius of not less than 5 per cent of the diameter of the crank shaft and are to have a smooth finish.

Oil holes at the surfaces of crank pins and journals are to be rounded to an even contour with a smooth finish.

Crank Shafts for Compressors of Other Designs

336 The particulars of crank shafts for double acting or compound compressors, and for other refrigerants or arrangements, are to be submitted for special consideration.

Maximum Working Pressures

337 The components of primary refrigerant pressure systems including piping, stop valves and headers are to be designed for a maximum working pressure of not less than :—

105 kg/cm² (1500 lb/in²) for carbon dioxide (CO_2)

17,5 kg/cm² (250lb/in²) for ammonia (NH_3) and monochlorodifluoromethane ($CH\ Cl\ F_2$)

10,5 kg/cm² (150lb/in²) for dichlorodifluoromethane ($C\ Cl_2\ F_2$)

In the case of crankcases which are exposed to the refrigerant pressure the design pressure is to be not less than :—

14 kg/cm² (200 lb/in²) for ammonia and monochlorodifluoromethane

7 kg/cm² (100 lb/in²) for dichlorodifluoromethane

Crankcases designed for a lower pressure are to be provided with a pressure relief valve arranged to lift at the design pressure and the discharge led to a safe place.

If desired a lower design pressure may be considered for other parts of the low pressure side of the system.

The design pressure for other refrigerants which may be proposed will be considered on application, but as a general guide this will be the saturated vapour pressure at 46°C (115°F).

Refrigerant Pressure Vessels

338 Welded cylindrical pressure vessels which are of steel construction and exposed to the pressure of the refrigerant are to be constructed in accordance with the requirements of J 1 to J 6 so far as applicable and the pressure tests are to comply with 346.

339 Where ammonia is the refrigerant, pressure vessels are to be constructed to not less than Class 2/2 fusion welded requirements.

340 Where pressure vessel shells are made of steel tube the tubes are to comply with the requirements of Q 7 and E 5 so far as applicable, except that the formula for determining the minimum thickness of straight shells as defined in E 512 shall be modified to:—

$$T = \frac{PD}{2f + P} + 0{,}75 \text{ mm} \quad \left(T = \frac{PD}{2f + P} + 0{\cdot}03 \text{ in}\right)$$

The pressure tests are to comply with 346.

341 Where ammonia is the refrigerant, pressure vessel shells are not to be manufactured from lap welded pipes.

342 Where pressure vessels are of forged seamless construction, they are to comply with the requirements of J 201 and Q 6 so far as applicable, and the pressure tests are to comply with 346.

343 Where it is proposed to construct pressure vessels of materials other than steel, or not of cylindrical form, full particulars will be required for special consideration.

Pressure Pipes

344 Steel piping for primary refrigerants is to comply with the requirements of E 5, except that a corrosion allowance of 1 mm (0·04 in) be added to the formula in E 512.

Butt welding of pipe lengths in lieu of flanged joints is to be carried out as required in E 5 under the supervision and to the satisfaction of the Surveyors.

Where the pipes are galvanized, a short part at the ends about 100 mm (4 in) long, is either to be left ungalvanized or the galvanizing is to be removed before welding.

345 Where it is proposed to use pipes of materials other than steel, full particulars are to be submitted for consideration.

Pressure Tests

346 The pressure tests as in Table N 3.3 are to be witnessed by the Society's Surveyors at the makers' works. The hydraulic test may be carried out with any suitable liquid. When it is inconvenient to test the large NH_3 (ammonia) condensers and evaporators by submersion in water the shells may be charged with air and gas, and tested by some suitable means. In the case of $C\ Cl_2\ F_2$ (dichlorodifluoromethane) and $CH\ Cl\ F_2$ (monochlorodifluoromethane) a suitable gas may be used in lieu of air.

Where difficulty may arise in testing components separately, proposals to test more than one component as a unit should be submitted for consideration in cases where the required test pressures are different for the separate components.

Tests after Erection on Board Ship

347 Carbon dioxide systems are to be examined for gas leaks when the system is charged. Ammonia and monochlorodifluoromethane systems are to be tested to a gas or air pressure of not less than 14 kg/cm² (200 lb/in²).

Dichlorodifluoromethane systems are to be tested by a suitable gas to a pressure of not less than 7 kg/cm² (100 lb/in²).

Brine systems are to be tested to a hydraulic pressure of double the working pressure but not less than 3,5 kg/cm² (50 lb/in²). Where the hydraulic test is not reasonably

TABLE N 3.3

Refrigerant	Component	Minimum Test Pressure: Hydraulic kg/cm² (lb/in²)	Minimum Test Pressure: Air* kg/cm² (lb/in²)
CO_2	Components subject to gas pressure:—		
	Compressor cylinder blocks, stop valves, condenser and evaporator coils, and other components.	210 (3000)	105 (1500)
	Fusion welded and seamless pressure vessels in accordance with 338, 340 and 342.	as per J 445	105 (1500)
	Pressure piping in accordance with 344.	as per E 523	105 (1500)
NH_3 and $CH\,Cl\,F_2$	Components subject to gas pressure:—		
	Compressor cylinders and stop valves.	42 (600)	21 (300)
	Compressor crankcases	21 (300)	10,5 (150)
	Condenser, evaporator and air cooler coils.	105 (1500)	35 (500)
	Condenser and evaporator coils or grids welded to headers, and other components.	35 (500)	17,5 (250)
	Fusion welded and seamless pressure vessels in accordance with 338, 340 and 342.	as per J 445	17,5 (250)
	Pressure piping in accordance with 344.	as per E 523	17,5 (250)
$C\,Cl_2\,F_2$	Components subject to gas pressure:—		
	Crankcases.	14 (200)	10,5 (150)
	Small machines with cylinders up to 115 mm (4·5 in) dia. where the cylinders and crankcases are in one casting.	21 (300)	14 (200)
	Fusion welded and seamless pressure vessels in accordance with 338, 340 and 342.	as per J 445	10,5 (150)
	Pressure piping in accordance with 344.	as per E 523	10,5 (150)
	All other components in the system.	24,5 (350)	14 (200)
	Cooling liquid side of refrigerant condensers.	2WP but not less than 1 kg/cm² (15 lb/in²)	
Brine	Air cooler coil assembly.	7 (100)	
	Cast iron casings of refrigerant evaporators.	2WP but not less than 1 kg/cm² (15 lb/in²)	
	Steel casings of refrigerant evaporators on suction side of pump.	2 × head pressure but not less than 2 kg/cm² (30 lb/in²)	
	Steel casings of refrigerant evaporators on discharge side of pump.	2WP but not less than 3,5 kg/cm² (50 lb/in²)	
	Open casings of brine evaporators.	Filled to top	

*Component submerged in water at 32°C (90°F).

possible, sections of brine leads (service pipes) which have to be insulated before the circuits are complete may be tested by an air pressure of 6 kg/cm² (90 lb/in²).

Oil Separators

348 Suitable oil separators with drains are to be provided to the refrigerant lines. If wire gauze is used in the separator it is to be sufficiently robust and supported to prevent disintegration.

Filters (strainers)

349 Suitable filters are to be provided in the refrigerant gas lines to compressors and in the liquid lines to the regulators. Wire gauze in filters is to be sufficiently robust and supported to prevent disintegration. A filter may be combined with the oil separator required by 348.

Refrigerant Driers

350 Driers are to be fitted in monochlorodifluoromethane and dichlorodifluoromethane refrigerant systems, and the arrangement is to be such that the drier can be by-passed, isolated and opened up without interrupting plant operation.

Brine Systems

351 Where brine is the cooling medium it is recommended that the "closed" system with a brine balance tank be adopted in every case.

Safety Devices

352 A pressure relief valve and/or safety disc is to be fitted between each compressor and its gas delivery stop valve, the discharge being led to the suction side of the compressor. Where the motive power for the compressor does not exceed 10 kW the pressure relief valve and/or safety disc may be omitted.

353 All pressure vessels of refrigerant systems which could become filled with liquid refrigerant and isolated are to be provided with safety discs and relief valves in series, or other approved arrangements, the discharge being led to a safe place above deck.

354 Suitable spring-loaded safety valves are to be provided to the cooling liquid side of condensers and the brine side of evaporators where the pressure from any pump connected could cause a pressure in excess of the maximum working pressure.

Access to Plant

355 The arrangements are to be such that all components of the refrigerating machinery can be readily opened up for inspection or overhaul. Space is to be provided for the withdrawal and renewal of the tubes in "shell and tube" type evaporators (brine coolers) and condensers.

356 Where the coils of "coil-in-casing" type evaporators (brine coolers) and condensers are unwieldy and cannot readily be withdrawn, two suitably arranged inspection holes are to be provided in the top plate, in the sides at about half height and in the sides at the bottom. The holes are to be as large as practicable and not less than 230 mm × 150 mm (9 in × 6 in).

Manual Control

357 Where plants are operated by thermostatic refrigerant control, efficient manual controls are also to be provided, and the arrangement is to be such that thermostatic controls can be by-passed and isolated.

As an alternative, duplicate thermostatically operated refrigerant control valves may be fitted, each valve to be capable of the required duty and operable with the other out of action.

Refrigerating Plant of Other Design

358 Particulars of refrigerating plant of designs other than those mentioned in these Rules (e.g. steam jet vacuum refrigeration plants) are to be submitted for special consideration.

Cooling Appliances in Refrigerated Chambers

359 Chambers may be refrigerated by pipe grids on the ceiling and sides or by the circulation of air over coolers.

360 Refrigeration by pipe grids in the chamber is to be effected by the circulation of brine, except in the case of installations or chambers of very small capacity when the direct expansion of the refrigerant will be considered. The pipe grids in each chamber are to be arranged in not less than two sections. Each section is to be fitted with valves or cocks so that it can be shut off.

361 Either brine or the direct expansion of the refrigerant may be employed in the coils of air coolers. The coils are to be arranged in not less than two sections each of which is to be capable of being readily isolated when necessary.

362 The brine or direct expansion leads to, and returns from, the cooling appliances in each chamber are preferably to be in duplicate.

363 In order to minimise the dehydration of the cargo and the frosting of the cooling elements, it is recommended that the cooling appliances in each chamber should be designed to maintain the required minimum temperature under the maximum difference of not more than 4,5degC (8degF) between the cooling medium and the chamber.

364 Where the joints of brine pipes are made by screwed couplings, the pipes, coupling and back nut threads are to be a good fit and the thickness of the pipes at the bottom of the screw thread is to be not less than 2,5 mm (0·1 in).

365 Where the joints of air cooler and grid piping are butt welded they are to comply with 344.

366 Steel brine and refrigerant piping, grids, joint sleeves and coils within the refrigerated cargo chambers, or where embedded in insulation, or individually insulated are to be galvanized externally. Where such pipes are connected by screwed couplings or by butt welds, the screw threads clear of the couplings or the butt welds and the adjoining ungalvanised portions of the piping, are to be suitably coated and taped after pressure testing to prevent corrosion. The locations of the joints are to be marked on the outside of the insulation.

367 Brine tanks and piping should not be galvanized on the brine side. In cases where any parts of the brine system are so treated, the brine cooling and return tanks, if closed, are to be provided with a ventilating pipe or pipes led to the atmosphere in a location where no damage will arise from the gas discharged, and the ventilating pipes are to be fitted with wire gauze diaphragms which can readily be removed. Where the brine tanks are not closed, the compartments in which they are situated are to be efficiently ventilated.

368 Means are to be provided for defrosting air coolers.

369 Air coolers are to be provided with trays of suitable depth arranged to collect all water condensate. The trays are to be provided with drains at the bottom so that the whole of the condensate can be drained away when the chambers are in service.

370 Access arrangements to air cooler fans and fan motors are to be such that both fans and motors may be readily removed for repair or renewal when the chambers are loaded with refrigerated cargo. Access for servicing only is required in cases where duplicate fans and motors, each capable of the full duty, are installed ready for use; this also applies to centrifugal type fans but not to their motors.

371 The air circulation system is to be arranged for positive air delivery to, or suction from, all parts of the chamber, including any space within hatch coamings.

372 Where it is intended to carry fruit cargoes which may be adversely affected by low temperatures, into sea areas where the temperature may be below the carrying temperature, facilities for heating the chambers are to be provided.

Air Refreshing Arrangements

373 Where chambers are intended for the carriage of gas-generating cargoes, air refreshing appliances are to be provided.

The position of the air inlets is to be carefully selected to minimize the possibility of vitiated air from any source entering the chambers. Each chamber is to be provided with individual inlets and discharges, having airtight closing appliances.

Section 4

CARGO CHAMBERS

Construction

401 Each individual chamber is to be of steel construction throughout and hose-tested for tightness, or tested more thoroughly by gas and air under slight pressure when required by the Owners.

402 At the request of Owners, special consideration will be given to the construction of divisional bulkheads of materials other than steel, between refrigerated cargo chambers where the chambers concerned are intended for cargoes which will not taint or otherwise adversely affect the cargo in any other chamber.

NOTE.—Gases given off by one description of fruit may adversely affect other descriptions by promoting rapid ripening.

403 Hatch plugs and their supports, chamber, air cooler and other access doors, tonnage openings, bilge limbers and plugs are to be made as airtight as possible.

404 Ventilators, ducts or pipes passing through refrigerated chambers to other compartments are to be made airtight and efficiently insulated. Ventilators to refrigerated spaces, if fitted, are to be provided with airtight closing appliances.

Airtightness of the Bulkheads and Decks

405 Where refrigeration pipes pass through bulkheads or decks of refrigerated cargo chambers they are not to be in direct contact with the steelwork, the holes through which they pass are to be true and of suitable finish for effectively sealing by the method intended. It is recommended that holes be trepanned and not burnt out. The airtightness of the bulkheads and decks is to be maintained (*see also* 408 and 413).

Airtightness of Chambers

406 The foregoing paragraphs, 401 to 405, are mainly concerned with infiltration of odours, gases, water vapour and air, which may taint or adversely affect the refrigerated cargo or the insulation, or cause undesirable frosting of cooling equipment. With this object in view it is also recommended that insulation lining, bilge limbers and plugs, hatch plugs, chamber and access doors be constructed of water vapour-resisting material, or covered with such material, and sealed, where exposed to bilges or external conditions.

Insulation

407 Steelwork is to be thoroughly cleaned and coated in accordance with D 3102 and D 3103 and is to be examined for airtightness of fittings before insulation is applied.

Insulating material approved by the Committee is to be used throughout, and the thickness of insulation over all surfaces and the manner in which it is supported are to be in accordance with the approved specification and plans.

The insulation is to be efficiently packed and, where it is of slab form, the joints are to be butted closely together and staggered, unavoidable crevices being filled with insulating material. Bitumen should not be used for filling crevices.

408 Pipes carrying the refrigerating medium are not to be in contact with the steel structure and are to be effectively insulated outside the chambers they serve, except within insulated brine cooler and control rooms (*see also* 405 and 413).

Cross-references

409 For insulation of oil storage tank tops and bulkheads, *see* E 345 and E 346.

For pipes in refrigerated spaces, *see* E 416 to E 418.

For drainage of refrigerated spaces and cooler trays, *see* E 211 to E 216.

For use of fork lift trucks in refrigerated spaces, *see* D 418.

Protection of Insulation

410 The insulation in way of the hatchways and about 0,6 m (2 ft) beyond on the tank top and the tunnel top is to be protected with hardwood sheathing about 50 mm (2 in) thick, or to have similar protection.

Access Plugs and Panels

411 Insulated plugs are to be provided in the insulation where required for easy access to the bilges, bilge suction roses, cooler and space drains and tank manhole doors. Removable panels are to be provided for access to tank air and sounding pipes and drains.

It is recommended that, where no air space is provided below the insulation on the tank tops and the floor covering above the insulation is reinforced asphalt, a number of small insulated inspection plugs be fitted for leakage detection.

Where "loose fill" insulation is fitted and lined with metal it is recommended that airtight inspection plates be provided at the top of vertical surfaces to facilitate inspection and making good any settlement.

Fire-resisting Insulation

412 The insulation in way of coal bunkers and of any surfaces exposed to excessive heat is to be of approved fire-resisting material. Where wood grounds are used for supporting insulation, asbestos strips are to be fitted between the wood grounds and the steelwork to which they are attached.

Where pipes carrying the refrigerating medium pass through bunkers the pipes may be packed with granulated cork but there is to be a thick outer covering of fire-resisting material and the whole is to be protected by steel plates which are to be sealed for airtightness.

Watertight Bulkhead Fittings

413 Where cooling pipes pass through watertight deck plating and bulkheads, the pipes are not to be in contact with the steelwork, and the fittings and packings of the glands are to be both fire-resisting and watertight (*see also* 405 and 408).

Airtightness of Insulation Lining and Air Ducts

414 Air ducts and insulation linings are to be so constructed and fitted that moving air is prevented from entering the insulation. Special care is necessary where cooling pipes, air refreshing ducts, fan supports, etc., protrude through the lining.

Cargo Battens

415 Cargo battens are to be secured to the insulation linings at the sides and bulkheads of chambers and at other vertical surfaces such as large rectangular section pillars, to provide a space for the circulation of air between the surfaces and refrigerated cargo. Cargo battens need not be fitted in way of air ducting, screens and cooler casings. The battens are to be arranged to suit the direction of air flow, and their outer edges are to be chamfered.

Battens should generally be about 50 mm $\times$ 50 mm (2 in$\times$2 in) spaced approximately 400 mm (16 in) apart, but smaller battens at closer spacing will be considered in conjunction with the air circulation system and the types of cargo to be carried.

416 Cargo battens of not less than 75 mm$\times$75 mm (3 in$\times$3 in) are to be secured over the tunnel top insulation.

Stiffening of Insulation Linings and Air Ducts

417 Insulation linings and air screens on the sides of chambers are to be suitably stiffened to prevent crushing by cargo, in particular where ship sides are curved inwards and according to the nature of the cargo, whether general or refrigerated, which the Owners intend to carry in the chambers. Air duct sides or insulation linings which may have to support heavy loads are to be constructed to Owners' requirements.

Galvanizing of Fixtures

418 All steel bolts, nuts, hangers, brackets and fixtures which support or secure cooling appliances, insulation, meat rails, etc., are to be galvanized.

Thermometers

419 Thermometers are to be of approved type, number and position in each chamber.

420 Thermometer tubes with their flanges and covers are to be insulated from the deck plating, and on weather decks they are to be so arranged that water will not run down the tubes when taking the temperatures.

421 The inside diameter of thermometer tubes is to be not less than 50 mm (2 in) and the tubes are not to be in contact with cold decks.

422 Where thermometer tubes pass through compartments other than that which they serve, they are to be efficiently insulated.

423 When electric remote reading temperature measurement is used in lieu of direct reading thermometers for the cargo chambers or air circulation system, the instruments and equipment are to be of approved type and are to comply with 424 to 430 and N 501.

424 Performance is to be satisfactory and accuracy is to be maintained during voltage and frequency fluctuations given in M 105, at all ambient temperatures up to and including those given in M 106, and in addition, construction is to comply with M 107 where applicable.

425 The readings of temperature shall be accurate to within $\pm$0,15degC ($\pm$0·25degF) of the true temperature in the range −3°C to +3°C (27°F to 37°F), and to within $\pm$0,25degC ($\pm$0·5degF) in other parts of the temperature range. These requirements will apply at all ambient temperatures to which the instrument and connecting parts may normally be exposed in use up to 50°C (122°F), and in the usual conditions of inclination and vibration associated with marine service.

For scale instruments, the scale deflection should not be less than 5 mm/degC or 0·2in/degF with division markings enabling the indication to be estimated within one-tenth of

a degree. The range of temperature will normally be between −29°C and +21°C (−20°F and +70°F).

In the case of instruments having both scales the deflection for the Fahrenheit scale should not be less than 0·2 in/degF with the Centigrade scale graduated to correspond.

426 At least two instruments are to be provided for each installation, with the sensing elements so connected that in the event of a failure of any one instrument, at least one sensing element will be operative for each chamber, either in the chamber or in its air circulation system.

Where a data logger is installed and all the sensing elements are connected to this single instrument, at least one sensing element in each chamber or in its circulating air system is to be connected to a separate instrument of approved type. The display of data loggers is to be in digital form or other equally effective visual indication, registering to one-tenth of a degree.

427 Where galvanometers are fitted, two are to be provided for each indicating instrument and a checking resistance fitted.

428 Where instruments have individual power supply units a spare power unit, e.g. transformers and rectifier or battery is to be provided for each instrument.

429 All temperature sensing elements are to be permanently connected, plug and socket connections not normally being acceptable between the elements and the instruments.

Wiring between the sensing elements and the instruments is to be in accordance with Chapter M. All junction boxes are to be provided with cable glands and all connections are to be of a permanent nature, such as soldered or compression type connections.

430 In order to obtain type approval, plans and specifications of the temperature indicating instrument and equipment are to be forwarded for examination. These are to include details of all components, of the sensing elements, leads and sheathing, and of selector switches and junction boxes.

The instrument and equipment are to be constructed in accordance with the approved plans and specifications.

In order to determine the suitability of the instrument and equipment, the Surveyors will examine a typical installation at the Makers and witness appropriate tests to determine that the degree of accuracy complies with 425. The ability of the instrument to withstand vibration, shock and other typical marine service conditions will be given particular attention.

Section 5

TESTS AFTER COMPLETION

Thermometers

501 All thermometers and equipment for measuring chamber and air suction and delivery temperatures are to be installed on board in accordance with the approved plans and the relevant paragraphs of N 4, and the whole installation completed to the satisfaction of the Surveyors.

Each thermometer is to be checked for accuracy by the contractors and a statement giving the readings to the nearest tenth of a degree at the freezing point of water handed to the Surveyors. The Surveyors may use their discretion as to whether check tests are necessary.

In the case of electric remote reading instruments a statement of calibration for each instrument indicating the method employed is to be supplied.

Air Cooler Fan Outputs and Air Circulating Arrangements

502 Air cooler fans are to be tested by the contractors after the air circulating system has been completed and a statement of the results for each chamber handed to the Surveyors. The statement is to show the static pressure, the cubic feet of air circulated per minute, the fan speed and the power consumption. The air circulation arrangements in the chambers are to be checked for distribution.

Refrigeration Test

503 All plant is to be tested under working conditions and the capabilities of the installation checked by a heat balance test.

Before the commencement of the test the Surveyors are to satisfy themselves that the electrical instruments, gauges and thermometers are accurate.

The chambers are to be cooled down to the temperatures required in the class notation, but not necessarily at the balance period. Unless the decks are insulated so that the steel is exposed to the ambient temperature (*see* D 423) the chamber temperatures are not to be reduced by more than 1degC (2degF) below the notation temperatures except by special arrangement and with the agreement of the Owners and the Builders.

When the chamber balance test temperatures have been reached they are to be maintained constant for a stabilising period during which heat is removed from the insulation, etc., in the chambers, and thereafter the temperatures maintained constant for a balance period of six hours, or longer if found necessary.

To maintain steady balance temperatures compressor speed or power input to the fan motors may be varied, or if necessary compressors may be run on stop-start cycles. Cylinder unloading should be avoided where possible and devices for varying cylinder duty should not be used. All such adjustments and stop-start cycles are to be carefully logged.

504 Observations are to be recorded from the beginning of cooling down to the end of the test. In the early stages logging may be at intervals of about four hours, but external temperatures should be logged hourly for the final eighteen hours of the test, and all other relevant temperatures and pressures, speed and power consumption of compressor and fan motors, power consumption of brine and cooling water pumps logged hourly for the final twelve hours of the test.

505 Where an installation is to be completed and tested during a period when extremely low external temperatures are probable and a reasonable difference between the external and internal temperatures will not be possible without reducing the chamber temperatures below the level referred to in 503, the case is to be submitted for special consideration.

506 In cases where it is reasonable to believe that the refrigerating plant is inefficient an output test on the plant may also be required.

Air Cooler Defrosting Arrangements

507 The air cooler defrosting arrangements are to be tested.

Section 6

SPARE GEAR

601 The following spare gear will be required in all cases :—

- 1 fan impeller of the propeller type of each size used.
- 1 set of the wearing parts of the crank shaft seals for each compressor where the crank case is subject to the refrigerant pressure.
- 1 set of crank shaft coupling bolts of each size used.
- 1 set of motor coupling bolts and washers, of each size used.
- 1 compressor piston with piston or connecting rod complete, of each size used.
- 1 complete assembly of each size of compressor suction and delivery valve.
- 1 complete set of packing for CO_2 compressor piston rod glands of each size used.
- 1 set of the working parts, together with packing and piston leathers, for the lubricating oil pump for CO_2 compressor rod glands.
- 1 gas regulator valve of each size used.
- 1 float regulator assembly of each size used.
- 1 set of suction and delivery valves for cooling water, air and brine pumps, of each size used.
- 1 set of driving belts of each size used.
- Sundry lengths and bends of piping together with flanges, couplings and screwing appliances.
- Sundry cocks, valves, flanges and fittings.
- Assorted bolts, nuts, studs, packing and joint rings.
- 5 per cent of the total number of electrical or tube thermometers, but not less than two of each.
- Not less than two standard thermometers of the necessary temperature range.
- 1 spare battery for each electric thermometer indicator fitted.
- 1 hydrometer, where brine is the cooling medium.
- 1 halide lamp leak detector, where dichlorodifluoromethane or monochlorodifluoromethane is the refrigerant.
- 2 safety valve springs of each size used.
- 6 safety discs of each size used.

In cases where approval is given to alternative arrangements under N 104, additional spare gear may be required according to the circumstances of the case.

602 Where steam driven air circulating fans are fitted, the following spare gear will be required :—

For each size used :—

- 1 crank shaft.
- 1 steam piston and rod complete.
- 1 steam cylinder cover.
- 1 set of connecting rod top and bottom end bearing bushes, and bolts complete.

603 Where the refrigerating machines are direct driven by steam engines or by oil engines, the spare gear is to be in accordance with Chapter K.

604 Where any component of the refrigerating plant is electrically driven the spare gear is to be in accordance with M 2102, and in the case of fan motors, M 2104, except where a duplicate fan motor (*see* N 370) is installed ready for use.

605 It is assumed that the Owners will arrange for the necessary reserve supply of the refrigerant, calcium chloride and oils for the voyage intended.

Section 7

INSTALLATIONS NOT CONSTRUCTED UNDER SURVEY

701 When classification is desired for an installation not constructed under the supervision of the Society's Surveyors, application is to be made to the Committee in writing.

702 Full particulars and plans are to be forwarded for consideration, together with the particulars of the materials of the crankshafts, pressure vessels and pressure piping. The requirements of N 202 are to be used for guidance in regard to the information required.

703 A special examination is to be made at least to the extent required for Subsequent Special Surveys. (*See* N 849 to N 857.)

704 The thickness and material of the insulation, the particulars of the frames, beams, stiffeners and other steel work within the insulation, the air coolers and/or chamber grid piping, the compressors, evaporators and condensers are to be verified, and the particulars of the other components of the refrigerating plant are to be verified so far as practicable.

705 The installation is to conform with the requirements of N 2, N 3, N 4 and N 6, so far as applicable.

706 A test is to be carried out in accordance with N 503 to N 505, and air circulation arrangements in the chambers are to be checked for air distribution.

Section 8

PERIODICAL AND OTHER SURVEYS

Incidence of Surveys

801 For the retention of the class assigned, installations are to be subjected to the periodical surveys specified in the following paragraphs.

Running Survey

802 A Running Survey as detailed in 815 to 829 is to be held at intervals of twelve months, and as detailed in 830 to 837 at the intervals stated therein.

Where desired by the Owners, Running Surveys may be held at shorter intervals of time.

In special circumstances, the Committee will be prepared to consider postponement of a Running Survey for a period not exceeding two months, provided application is made by the Owners prior to the due date of the survey and provided a Loading Port Survey is carried out as near to this date as possible.

Special Survey

803 A Special Survey as detailed in 839 to 857 is to be held at four-yearly intervals, the first four years after the date of the survey for classification and thereafter four years from the date of the previous Special Survey.

A Special Survey will normally become due at the same time as a Running Survey, but when they do not coincide, the date assigned to the Special Survey will be that of the Running Survey.

Where it is inconvenient for Owners to fulfil the Special Survey requirements at the due date, the Committee will be prepared to consider its postponement, either wholly or in part, for a period not exceeding twelve months from the due date, provided prior application is made by the Owners, and provided the Running Surveys continue to be held at the specified intervals. Any special circumstances which may arise will require to be dealt with as necessary.

Continuous Special Survey of Insulation

804 At the request of Owners, the Committee may agree to the Special Survey requirements of 844 to 846 being carried out on a Continuous Survey basis on ships in which the Continuous Hull Survey system has been accepted. In these cases the insulation in the compartments concerned and the insulation of the refrigerant piping should be exposed or removed as required by the Surveyors, in rotation, with an interval of five years between consecutive examinations of each part.

If the examination during Continuous Surveys reveals any defects, further parts are to be opened up and examined as considered necessary by the Surveyor.

Survey of Repairs

805 Where any essential repairs and/or renewals are effected to an installation, they are to be carried out under the supervision and to the satisfaction of the Society's Surveyors. Repairs and renewals effected at ports where there is no Surveyor to this Society are to be surveyed by one of the Society's Surveyors at the earliest opportunity.

Alterations and Additions

806 Plans and particulars of any proposed alterations or additions to the refrigerated cargo chambers or the refrigerating plant are to be submitted for approval before the work is put in hand, and the work is to be carried out under the supervision and to the satisfaction of the Society's Surveyors.

Record of Surveys

807 The date following the class notation "Lloyd's RMC" on the certificate indicates the date when the installation was first classed.

The notation "RS with date" indicates the date of the last Running Survey.

The notation "SRMC with date" indicates the date of the last Special Survey.

When the requirements of the Continuous Special Survey and all other requirements of the Special RMC Survey have been completed the notation assigned will be "SRMC (CSI) with date".

The notations when assigned will be recorded in the appropriate section of the Register Book and in the supplements.

Notice of Surveys

808 It is the responsibility of Owners to ensure that all surveys necessary for the maintenance of class are carried out at the proper time under the supervision of the Society's Surveyors

It is, however, the normal practice of the Society to give timely notice to Owners when Periodical Surveys of Refrigerated Cargo Installations become due, but the non-receipt of such notice does not absolve Owners from this responsibility.

Loading Port Survey

809 When a Loading Port Certificate is required by the Owners or their representatives, a survey as detailed in 810 to 814 is to be carried out at the loading port. The certificate is not in respect of the cargo to be loaded or the manner in which it is to be stowed.

In the case of ships engaged on voyages of less than two months duration, a Loading Port Certificate will be considered as valid for two months, provided the cargoes carried are of such a nature as not to damage the insulation or appliances in the insulated chambers, nor to affect by taint or mould the refrigerated cargoes loaded during that period.

810 The chambers are to be examined in an empty state to ascertain that they are clean and free from odour which may adversely affect the cargo to be loaded, that the brine or other refrigerant pipe grids, cooler coils and connections are free from leakage, that the fixed cargo battens on the vertical surfaces are in good order, that cargo gratings or dunnage battens are provided for the floors or decks and that no damage has been sustained to the insulation or its lining prior to the loading of the refrigerated cargo. Any indications of defective insulation not considered to warrant immediate attention should be noted and specially reported.

811 The Surveyor is to satisfy himself that all scuppers and bilge suctions draining insulated spaces are in good working order, and that the liquid seals are primed.

812 The refrigerating installation is to be examined under working conditions, and the temperatures in the cargo chambers are to be noted.

813 If the ship loads at more than one port, one survey only at the first loading port will be required, provided it includes the examination of all the chambers which are to be used for refrigerated cargo during the voyage and general cargo is not subsequently carried in any of the chambers prior to loading the refrigerated cargo.

814 If there is no Surveyor to the Society available at the loading port(s), or if none is obtainable from a port within a reasonable distance, the Committee will accept the report of a survey held at the loading port by a Surveyor appointed by Lloyd's Agent; or in any case where there is no Lloyd's Agent, the report of a survey held by a reliable Surveyor, if available; if no such Surveyor is available, a report signed by two competent engineers of the ship will be accepted.

RUNNING SURVEYS

General

815 Whenever practicable, the machinery in use is to be examined under working conditions on the ship's arrival at the port of discharge before the refrigerated cargo is unloaded.

Log books or other records should be examined and any breakdowns or indications of deficiency in the installation are to be noted and reported.

Cargo Chambers

816 The cargo chambers are to be examined throughout.

817 Insulation linings and fastenings on the sides, bulkheads and deckheads are to be examined as far as practicable for condition and airtightness. The removal of parts of the linings, or drilling, is not required unless insulation deficiency is known or suspected, but any indication of dampness or leakage into the insulation from tanks, decks, scuppers or other source is to be investigated.

818 The coverings on deck, tank top and tunnel top insulation are to be examined for condition and shrinkage. Where there is evidence of deterioration or dampness the insulation is to be tested by drilling and parts of the covering removed if found necessary.

819 Air ducting and cooler casings, and the fastenings and supports for ducts, grids and meat rails are to be examined as far as practicable for damage or deterioration.

820 Hatch plugs and supports, patent hatch covers and seals, chamber and access doors and frames, bilge and manhole plugs, air refreshing pipes and their closing appliances are to be examined for condition and airtightness.

821 The bilges are to be cleaned and suction pipes suction roses, sounding pipes and scupper non-return valves examined. The Surveyor should satisfy himself that all scuppers draining the chambers and cooler trays are in good working order.

Air Coolers and Grids

822 Air cooler coils, cooling grids and valves are to be examined. The Surveyor should satisfy himself that sections of the coils or grids are not choked and that the valves are in good working order.

823 Brine refrigerant cooler coils and grids are to be examined whilst under a pressure of 1,5 times the working pressure or 3 kg/cm^2 (40 lb/in^2) whichever is the greater.

824 Primary refrigerant cooler coils and grids are to be examined whilst under the refrigerant pressure prevailing in the system at the time of the survey, with the plant at rest and the regulating valves opened just sufficient to obtain an approximate balance of pressure throughout the system, and to avoid accumulation of liquid in the coils or grids.

Primary Refrigerant Pressure Vessels and Connections

825 The shells of "shell and tube" and "double pipe" type condensers and evaporators, separators, receivers, driers, filters and other pressure vessels, and the coil terminals of "coil in casing" type condensers and evaporators, are to be examined as far as practicable.

In the case of pressure vessels covered by insulation any evidence of dampness or deterioration of the insulation which could lead to external corrosion of the vessels or their connections is to be investigated.

Piping and Headers

826 Primary refrigerant gas and liquid pipes, brine piping, headers, condenser cooling water piping and valves are to be examined as far as practicable.

Where parts of the piping or headers are covered by insulation an examination of the insulation is to be made as in 825.

Thermometers

827 The thermometers for measuring the chamber, air suction, and air delivery temperatures are to be examined and where repairs or renewals are found necessary the thermometers concerned are afterwards to be checked for accuracy.

Each thermometer is to be tested for accuracy at intervals not exceeding the period between Special Surveys, but not necessarily all at one time. The Surveyor may at his discretion accept the results of thermometer tests carried out by a competent staff or contractor.

NOTE.—In a number of ships, thermometers of a type not approved by the Society have been fitted in addition to those required by N 419: the former need not be examined or tested.

Fans and Fan Motors

828 A general examination is to be made of air cooler fans, their motors, control gear and cables and the insulation resistance measured. The insulation resistance is not to be less than 100 000 ohms, and for the purpose of this test each item may be taken separately. The Surveyor may at his discretion accept the results of tests carried out by a competent staff or contractor.

Generating Plant

829 The generating plant supplying electric power to the refrigerating machinery is to be examined generally with a view to ascertaining that the plant is being efficiently maintained.

In the case of ships not classed with the Society, the Surveyor is to ascertain that periodical examinations of the generating plant continue to be held by the Classification Society concerned.

Compressors

830 Each reciprocating compressor, including those provided for sub-cooling the primary refrigerant, is to be opened up at intervals of two years and examined in accordance with (a) and (b) alternately.

(a) Cylinder bores, valves and seats, glands, relief devices, suction filters and lubricating arrangements are to be examined. Crankcase doors are to be removed for a general examination, and crankshaft bearing surfaces exposed if required by the Surveyor.

(b) In addition to the examination described in (a), pistons, piston rods, connecting rods, and the crankshaft are to be examined. Crankcase glands and the lower halves of main bearings need not be exposed if the Surveyor is satisfied as to alignment and wear.

831 Alternatively, each compressor may be opened up after each period of 5000 running hours and examined in accordance with 830 (a) and 830 (b) alternately, but the interval between examinations in accordance with 830 (b) is not to exceed four years unless in special circumstances an extension of this period is agreed by the Committee.

Where this system is adopted it will be the Owners' responsibility to maintain a record of the running hours of each compressor, and to ensure that neither periods of 5000 running hours between examinations, nor four years between examinations in accordance with 830 (b), are exceeded.

It will be the Surveyor's responsibilty to examine the records at Running Surveys and to report the number of running hours logged by each compressor since it was last examined.

Where other than reciprocating compressors are fitted, or where there is a programme of replacement instead of surveys on board, other survey arrangements may be necessary. Each case will be given individual consideration.

Condensers

832 The water end covers of "shell and tube" and "double pipe" type condensers are to be removed for examination of the tubes, tubeplates and covers, in rotation, approximately half the number of condensers to be examined annually so that all are examined in a period of two years.

Where there are several separate installations in a ship, the number of condensers to be examined annually will be specially considered for each case.

Condenser Cooling Water Pumps

833 The working parts of condenser cooling water pumps, including the standby pump which may be used on other services, are to be examined in regular rotation so that all are examined in a period of two years.

If there are two or more stand-by sources of cooling water supply the examination may be extended over a period of four years and is to include at least two stand-by pumps, approximately half the number of pumps to be examined in each two-year period.

Brine and Primary Refrigerant Circulating Pumps

834 The working parts of brine and primary refrigerant pumps are to be examined in rotation so that all are examined in a period of two years.

Prime Movers

835 Where a refrigerating compressor, water, brine or primary refrigerant pump is electrically driven, a general examination is to be made of the motor, control gear and cables and the insulation resistance measured as in 828, at the same time as the compressor or pump is being examined.

Where a compressor or pump is driven by a steam or internal combustion engine, all the working parts of the engine are to be opened up and examined in a similar manner to that specified for compressors in 830, at the same time as the compressor or pump is being examined.

Steam Jet Vacuum Refrigerating Plant

836 Steam jet plant forming the primary refrigerant system is to be examined in rotation at Running Surveys so that all parts, including flash chambers, water spray arrangements, thermo-compressor steam chambers, nozzles, condensers, pumps and ejectors are examined in a period of two years.

Spare Gear

837 The refrigerating plant spare gear is to be checked.

Survey Records

838 A Survey book or other permanent record is to be kept on board the ship to show the date of examination of

the various parts. This is to be available to the Surveyor at all times and is to be signed by the Surveyor on the occasion of each survey.

NOTE.—The Surveyor may ask for additional items to be opened up for examination if considered necessary at any survey.

FIRST SPECIAL SURVEY

839 In addition to the requirements for Running Survey as detailed in 815 to 837, the following are to be complied with.

840 Where the refrigerating machinery is driven by internal combustion engines and independent air compressors and air receivers exclusive to the refrigerating plant are installed, the working parts of the compressors and their intercoolers, filters, oil separators and safety devices are to be examined. The air receivers with their mountings, valves and safety devices are to be cleaned internally and examined internally and externally. If internal examination of the air receivers is not practicable, they are to be tested hydraulically to twice the working pressure.

841 The Surveyor is to satisfy himself that all pressure relief valves and/or safety discs throughout the refrigerating plant are in good order. No attempt, however, should be made to test primary refrigerant pressure relief valves on board ship.

842 In the case of steam jet vacuum refrigerating plants installed for sub-cooling the primary refrigerant liquid, the flash chambers and water spray arrangements, the thermo-compressor steam chambers and nozzles, the condensers, the cooled water circulating, condenser cooling and condensate extraction pumps, and the air pumps or ejectors are to be examined and, if considered necessary, the condensers are to be tested.

843 Sufficient insulation is to be stripped from insulated pressure vessels to permit of the condition of the vessels and their connections being ascertained. Care is to be taken that on replacement of the insulation the vapour sealing of the outer covering is made good.

844 Sufficient insulation is to be stripped from pipes carrying the refrigerating medium at various points of the system, both outside and inside the chambers, to permit of the condition of the pipes being ascertained. Care is to be taken that on replacement of the insulation the vapour sealing of the outer covering is made good.

845 Sufficient air trunking and insulation lining is to be stripped from the chamber overhead and vertical surfaces to permit of the condition of the insulation, insulation linings, grounds, supports, hangers and fixtures which support the insulation, grids, meat rails, etc., being ascertained. Care is to be taken that on replacement the ducts and linings are sealed against air blowing into the insulation.

846 Sufficient tank top insulation is to be stripped to permit of the condition of the grounds and inner insulation lining being ascertained.

847 Sea connections to condenser cooling water pumps are to be opened up and examined.

848 Steam pipes to steam engines driving refrigerating machinery, and to steam jet vacuum refrigerating plants are to be examined as required by C 10 if the temperature of the steam is over 454°C (850°F).

In the case of installations on unclassed ships, the Surveyors are to ascertain whether the steam pipes have been similarly dealt with by the Classification Society concerned, and if not, arrangements are to be made for the examination and tests in accordance with C 10.

SUBSEQUENT SPECIAL SURVEYS

849 In addition to the requirements for First Special Survey as detailed in 839 to 848, the following are to be complied with.

850 The coils of gas condensers of the "coil in casing" type are to be examined and tested to a pressure of 17,5 kg/cm^2 (250 lb/in^2) for dichlorodifluoromethane systems, 70 kg/cm^2 (1000 lb/in^2) for ammonia and monochlorodifluoromethane systems, and 140 kg/cm^2 (2000 lb/in^2) for carbon dioxide systems. Where it is impracticable to remove the coils they may be examined and tested in place.

851 The coils of evaporators (brine coolers) of the "coil in casing" type are to be examined and tested to a pressure of 14 kg/cm^2 (200 lb/in^2) for dichlorodifluoromethane systems, 35 kg/cm^2 (500 lb/in^2) for ammonia and monochlorodifluoromethane systems, and 105 kg/cm^2 (1500 lb/in^2) for carbon dioxide systems. Where it is impracticable to remove the coils they may be examined and tested in place.

852 Gas condensers of the "shell and tube" type, and gas evaporators (brine coolers) of the "shell and tube" type in which the primary refrigerant is in the shell, are to have the water or brine end covers removed and the shell pneumatically tested with the refrigerant or air, or a mixture of inert gas and refrigerant, to a pressure of 7 kg/cm^2 (100 lb/in^2) for dichlorodifluoromethane systems and 14 kg/cm^2 (200 lb/in^2) for ammonia and monochlorodifluoromethane systems.

853 Gas evaporators (brine coolers) of the "shell and tube" type in which the brine is in the shell are to have the primary refrigerant end covers removed and the shell hydraulically tested to twice the design pressure but to not less than 3 kg/cm² (40 lb/in²).

After refitting the end covers the primary refrigerant side is to be pneumatically tested as stated in 852, and an examination made as far as practicable for gas leakage in the shell with the brine connections removed.

854 Primary refrigerant liquid sub-cooling coils in flash chambers of steam jet vacuum refrigerating plants are to be examined and tested to the same pressure as that required for condensers in 850.

855 Where brine or water is used for sub-cooling the primary refrigerant liquid in heat exchangers of the "shell and tube" type, the heat exchangers are to be examined and tested in the same manner as that required for condensers in 852.

"Double pipe" type heat exchangers are to be examined so far as practicable with the gas piping under the same pressures as that required for condensers in 852 and the water or brine from the outlets is to be tested for gas leakage.

Other types of heat exchangers using brine or water are to be examined and tested at the discretion of the Surveyor according to the design of such equipment.

856 Primary refrigerant chamber grids or air cooler coils are to be tested in place to a pressure of 7 kg/cm² (100 lb/in²) for dichlorodifluoromethane, 10,5 kg/cm² (150 lb/in²) for ammonia and monochlorodifluoromethane systems, and 70 kg/cm² (1000 lb/in²) for carbon dioxide systems.

857 Steam pipes to steam engines driving refrigerating machinery, and to steam jet vacuum refrigerating plants are to be examined as required by C 10.

In the case of installations on unclassed ships, the Surveyors are to ascertain whether the steam pipes have been similarly dealt with by the Classification Society concerned, and if not, arrangements are to be made for the examination and tests in accordance with C 10.

Section 9

REFRIGERATED FREIGHT CONTAINERS WITH SELF-CONTAINED REFRIGERATING UNITS

General

901 Refrigerated freight containers with self-contained refrigerating plant carried on ships and under supervision and maintenance by the ship's staff as refrigerating installations, are eligible for classification. They are to comply with N 1 to N 8 in so far as they are applicable, together with the following paragraphs.

902 The Owners' name and an identification number are to be clearly marked on each container.

903 Where a container has not been constructed and tested as in the following paragraph 904, it is to be indicated on the container that it is not to be lifted in a loaded condition.

904 Where a container has been constructed for lifting in a loaded condition a deflection test of the structure is to be carried out on the container in a loaded condition under the supervision of the Surveyors.

At this test the container is to be lifted with the cargo space loaded with a uniformly distributed load in three successive stages up to 1,25 times the specified maximum cargo load, and the ratio of the deflection to the length of the container is not to be greater than 1 to 1200.

The empty weight of the container and the maximum cargo load are to be clearly indicated on the container.

905 Where a container is intended for carrying stacked with other similar containers, in addition to the lifting test in 904, the container is to be subjected to a downward load test equal to 1,8 times the maximum intended superimposed weight divided equally between the weight-bearing points.

The empty weight of the container, the maximum cargo load and the maximum superimposed stacking load are to be clearly indicated on the container.

906 Where a number of identical containers are being built at the same time the lifting test in 904, and if applicable the load test in 905, applied to one in every five containers may be accepted as sufficient.

907 Where it is intended to use fork lift trucks in a container, the suitability of the floor for the maximum intended weight of truck and load may require to be tested on one container or on a prototype floor.

908 A log book showing the particulars of the refrigeration of the container during each voyage is to be maintained, and this is to be made available to the Surveyor at each of the surveys required by 930.

Where the plant is operated by thermostatic control the intervals during which the machinery is working and at rest should be recorded occasionally, particularly during the period of maximum external temperature conditions of each voyage.

Class Notation

909 The class notation will be in accordance with N 1 except that where the refrigerant condenser is air cooled the class notation shown in N 101 will give the maximum ambient temperature instead of the maximum sea temperature, e.g., "to maintain temp. minus 12°C (10°F) with ambient temp. 40°C (104°F) maximum."

Where the refrigerating machinery is electrically driven and dependent on the ship's generators for power, the class assigned will be subject to suitable electric power being available at all times when the container is loaded with refrigerated cargo.

Special Survey during Construction

910 The requirements of N 2 are to be complied with in so far as they are applicable.

Refrigerating Plant

911 The requirements of N 3 are to be complied with in so far as they are applicable, except as modified by the following paragraphs.

912 Where two or more refrigerating units supply refrigeration to a container, the plant is to be capable of efficiently maintaining the minimum internal temperature under the maximum external conditions, to be specified in the class notation, when working 24 hours per day with any one of the refrigerating units out of action.

913 When one refrigerating unit supplies refrigeration to a container, the unit is to be capable of efficiently maintaining the minimum internal temperature under the maximum external conditions, to be specified in the class notation, when working not more than 18 hours per day.

914 Where the refrigerant condenser is air cooled and the maximum gas discharge pressure is above the maxima specified in N 326 and N 337, the design pressure is to be correspondingly increased.

915 Where the design pressure is increased in accordance with 914, the test pressures specified in N 346 are to be increased proportionately.

916 Where "shell and tube" type evaporators (brine coolers) and condensers can be readily removed, the space for the withdrawal and renewal of tubes in accordance with N 355 will not be required.

917 Where the power for the container refrigerating unit on board ship is provided by an internal combustion engine installed with the unit, the container is to be carried on deck.

918 Where an internal combustion engine is installed with the refrigerating unit for use only on land, the container may be carried in a well ventilated space below deck provided that before placing the container on board, the fuel tank is either drained or removed and stored in a safe place on the ship.

Cargo Space

919 When a container is of metal or timber panel construction the joints of the inner lining panels are to be made airtight and the joints of the outer lining panels are to be efficiently vapour sealed on both sides. Where it is not possible to apply the vapour seal on the inside of the outer panel joints the outer surface of the insulation is to be vapour sealed. All the materials used are to be suitable for the temperatures involved and without detriment to the cargoes carried.

Cargo doors, hinges and fastenings are to be of robust construction and the doors airtight.

920 Cargo battens or other suitable means are to be provided to ensure adequate space for circulation of air between the cargo and the linings.

921 The containers are to comply with the requirements of N 404 and N 405, N 407 and N 408, N 414, N 417 and N 418 in so far as they are applicable.

922 Drains of not less than 19 mm (0·75 in) bore are to be provided from the cargo space and air cooler trays, and the drains are to be fitted with means of closure operable from outside the cargo space.

923 Thermometers are to be of approved type and position in the cargo space. Where thermometer tubes are provided the method of attachment is also to be approved.

Tests after Completion

924 Each completed container is to be tested in accordance with the requirements of N 5 in so far as they are applicable.

Spare Gear

925 Where two or more refrigerating units supply refrigeration to a container, the spare gear to be carried on the ship with container is to be in accordance with N 6 in so far as that Section is applicable.

926 Where a single refrigerating unit supplies refrigeration to a container, a complete spare compressor ready for fitting in place is to be carried on board the ship with the container, together with the spare gear required by 925, except those items which are included in the spare compressor.

927 Where a number of containers with identical refrigerating units are carried on a ship, one set of spare gear as required by 925 or 926, whichever is applicable, is to be carried on board for every ten or part of ten containers. This will apply up to a total of twenty containers carried but where the number exceeds this the additional spare gear required will be specially considered.

928 If at any time a group of containers is divided between two or more ships, spare gear as required by the foregoing paragraphs is to be carried on each ship.

Containers not Constructed under Survey

929 The requirements of N 7 are to be complied with in so far as they are applicable, except as amended by this Section.

Periodical and other Surveys

930 For the retention of the class assigned, periodical and other surveys are to be carried out in accordance with N 8 except as modified in the following paragraphs.

Loading Port Surveys

931 The requirements of N 810 and N 812 are to be complied with and, in addition, the Surveyor is to satisfy himself that the container is placed on board in such a position as to provide free access to it by the ship's personnel for servicing the refrigerating plant and noting the temperatures; and, where the refrigerant condenser is air cooled, to allow free flow of fresh air to, and heated air from, the condenser.

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932 Generating plant supplying power and the cables and connections to the refrigerating machinery are to be examined generally.

933 The Surveyor is also to satisfy himself that the drains from the cargo space and air cooler trays are clear and the closing devices are in order.

934 Where an owner desires a Loading Port Survey of a container which is to be loaded with refrigerated cargo ashore instead of on board the ship, the particular circumstances will require to be specially considered.

Running Surveys

935 The requirements of N 815 to N 837 are to be complied with so far as they are applicable. In addition, the cargo space and air cooler drains and their closing appliances are to be examined.

First Special Survey

936 The requirements of N 839 to N 848 are to be complied with so far as they are applicable.

937 Sufficient covering and insulation is to be stripped from the floor of the container to permit of the condition of the insulation, grounds and structure being ascertained.

Subsequent Special Surveys

938 The requirements of N 849 to N 857 are to be complied with so far as they are applicable, and in addition, those of 937.

Chapter P

MATERIALS FOR SHIP CONSTRUCTION

Note:—For list of steel manufacturers see Appendix following Chapter Q.

General

Materials used in the construction and for the equipment of ships are to be manufactured and tested in accordance with the requirements contained in the following sections of this Chapter:—

Section 1. General requirements for rolled steel products,
,, 2. Mild steel for hull structures,
,, 3. Higher tensile steel for hull structures,
,, 4. Steel rivet bars and manufactured rivets,
,, 5. Steel castings,
,, 6. Steel forgings,
,, 7. Steel anchors,
,, 8. Chain cable and steering chains,
,, 9. Steel wire ropes for standing rigging, towlines and mooring ropes,
,, 10. Fibre ropes,
,, 11. Approval of electrodes and wire-flux combinations for welding in hull construction,
,, 12. Aluminium alloy plates, bars and sections,
,, 13. Aluminium alloy rivets,
,, 14. Welding of aluminium alloys.

Section 1

GENERAL REQUIREMENTS FOR ROLLED STEEL PRODUCTS

Scope

101 This section gives general requirements for steel plates, sections, bars, tubes and other hollow sections used in hull construction.

Approval of Works and Method of Manufacture

102 Steel is to be manufactured at works approved by the Committee. A list of approved manufacturers is given in the Appendix at the end of Chapter Q.

The steel is to be made by the open hearth, electric furnace or oxygen processes or by other processes approved by the Committee. An oxygen process is defined as a process in which molten iron contained in a basic lined converter is refined by directing a jet of high purity gaseous oxygen onto the surface of the hot metal.

The steel making practice is to be such as to minimise the included non-metallic content of the finished steel. Acceptable de-oxidation practices are given under the specific requirements in subsequent sections of this Chapter.

The steel is to be cast in metal ingot moulds or by an approved continuous casting process. The size of the ingot or of the continuous cast billet or slab is to be proportional to the dimensions of the final product in order that the amount of mechanical work will be adequate to ensure a satisfactory steel structure in the finished product. Provision is also to be made for sufficient discard to be taken from the top and bottom of each ingot to ensure soundness in the portion used for further processing. Periodically and at the Surveyor's discretion sulphur prints or other suitable proving tests may be required to demonstrate that this has been fulfilled.

Testing and Inspection

103 The prescribed tests and inspection shall be carried out at the place of manufacture before despatch, but in the event of any material proving unsatisfactory during working or fabrication, such material shall be rejected notwithstanding any previous certificates, and the Surveyor may require further tests from other materials from the same batch.

All the test pieces are to be selected and stamped by the Surveyor or an authorised deputy and tested in his presence.

Surface Inspection and Dimensions

104 Surface inspection and verification of dimensions are the responsibility of the steelmaker, and acceptance by the Surveyors of material later found to be defective shall not absolve the steelmaker from this responsibility.

Identification of Materials

105 The steelmaker shall adopt a system for the identification of ingots, slabs and finished pieces which will enable the material to be traced to its original heat, and the Surveyors shall be given full facilities for so tracing the material when required.

Branding

106 Every finished item is to be clearly marked by the makers in at least one place with the Society's brand and the following particulars:—

(i) Agreed identification mark for the grade of steel.
(ii) Name or initials to identify the steelworks.
(iii) Number and/or initials to identify the heat.
(iv) Purchaser's identification mark if required by the purchaser.

Where a number of light materials are securely fastened together in bundles, the manufacturer may, subject to the agreement of the Surveyors, brand only the top piece of each bundle, or alternatively, a firmly fastened durable label containing the brand may be attached to each bundle.

Defacing of Rejected Material

107 In the event of any material, bearing the Society's brand, failing to comply with the test requirements, the brand is to be unmistakably defaced.

Mill Sheets

108 The Surveyor shall be supplied with at least two copies of the mill sheets or shipping statements of all accepted material which documents should be separate for each grade of steel. The documents shall contain, in addition to the description, dimensions, etc., of the material, the following particulars:—

(i) Purchaser's identification marks.
(ii) Identification of the heat.
(iii) Identification of the steelworks.
(iv) Identification of the grade of steel.
(v) Ladle analysis (elements controlled by the specification only).
(vi) Order or ship number for which intended.
(vii) If the ship steel is of rimming quality, this should be stated.
(viii) For higher tensile steel, the specified minimum yield stress and the specified tensile strength range are to be stated together with the actual carbon equivalent value (*see* P 302).

Maker's Certificate

109 Before the mill sheets or shipping statements are signed by the Surveyor, the manufacturer is required to furnish him with a certificate stating the material has been made by an approved process and that it has been subjected to and has withstood satisfactorily the required tests in the presence of the Surveyor or his authorised deputy. The following form of certificate will be accepted if stamped or printed on each mill sheet with the name of the steelworks and initialled for the makers by an authorised official:—

> "We hereby certify that the material herein described has been made by the........................process (process to be stated) approved by and in accordance with the Rules of Lloyd's Register of Shipping for Grade................steel, and is that which has been tested in the presence of the Society's representative with satisfactory results."

Facilities for Inspection

110 The manufacturers shall afford the Surveyors all necessary facilities and access to all relevant parts of the works to enable them to verify that the approved process is adhered to, and for witnessing the selection and testing as required by the Rules, and for verifying the accuracy of the testing equipment.

Steel not Produced where Rolled

111 When steel is not produced at the Works at which it is rolled, a certificate shall be supplied to the Surveyor at the rolling mill stating the process by which it was manufactured, the name of the manufacturer who supplied it, the number of the heat from which it was made and the ladle analysis. The works at which the steel was produced must be approved by the Committee.

Tensile Test

112 The tensile tests shall be carried out by competent personnel in an approved machine of adequate capacity. The machine shall be maintained in a satisfactory and accurate condition and shall be re-calibrated at approximately annual intervals. This calibration is to be carried out by a nationally recognised authority or other organisation of standing and is to be to the satisfaction of the Surveyor. A record of all calibrations shall be kept available in the test house.

The tensile strength is defined as the maximum load divided by the original cross-sectional area of the tensile test piece.

Section 2

MILD STEEL FOR HULL STRUCTURES

NOTE.—*These requirements are primarily intended to apply to steel not exceeding 50 mm (2 in) in thickness. For greater thicknesses, certain variations in the requirements may be allowed or required in particular cases after consideration of the technical circumstances involved.*

Freedom from Defects

201 (*a*) The minus tolerance in the thickness of plates and sections from those given on the approved plans is not to exceed:—

Nominal thickness "t"			*Tolerance*	
	mm	in	mm	in
Not exceeding	15,0	0·6	0,4	0·016
Over / Not exceeding	15,0 / 45,0	0·6 / 1·8	(0,02t+0,1)	(0·02t+0·004)
Over	45,0	1·8	1,0	0·04

The general standard as laid down by the Rules is to be maintained.

The thickness of plates is to be measured at positions which are approximately 40 mm (1·5 in) from an edge and 100 mm (4·0 in) from a corner.

(*b*) The steel is to be reasonably free from segregations, surface flaws and non-metallic inclusions. The finished material is to be free from cracks and lamination. It shall also have a workmanlike finish, and must not have been hammer dressed.

(*c*) Surface defects may be removed by grinding, provided that the thickness is in no place reduced to less than 93 per cent of the nominal thickness but in no case by more than 3 mm (0·125 in). The extent of such repairs shall be agreed in each case with the Surveyors, and the repairs shall be carried out under the Surveyors' supervision unless otherwise agreed.

(*d*) Surface defects which cannot be dealt with as above may be repaired by chipping or grinding followed by welding, subject to the Surveyors' consent and under their supervision, provided:—

(i) that after removal of the defect, and before welding, the thickness of the item is in no place reduced by more than 20 per cent,

(ii) that the welding is carried out by an approved procedure, by competent operators with approved electrodes, and that the welding is ground smooth to the correct nominal thickness,

(iii) that subsequent to the finish grinding, the piece may be required to be normalised or otherwise heat treated at the Surveyors' discretion. Re-normalising will always be required if the piece has been normalised before the repair.

Distinguishing Marks

202 The entire marking (*see* P 106) is to be surrounded by a clear mark in paint of the following distinctive colours:—

Grade A steel ... ... white
Grade B steel ... ... green
Grade C steel ... ... blue
Grade D steel ... ... red
Grade E steel ... ... yellow

Where the name of the steelworks is embossed on finished sections, only the Society's brand and items (i), (iii) and (iv) of P 106 need be surrounded by paint in appropriate colour.

Standard Tensile Test Piece

203 This piece shall have a rectangular cross-section with thickness equal to that of the material from which it is cut and a width of 25 mm (1 in) with a length between gauge marks of 200 mm (8 in). The parallel length shall not be less than 230 mm (9 in). The ends of the test piece may be increased in width to suit the grips of the machine, the transition between the different widths being made with a gentle curve.

The test pieces are to be cut with their lengths transverse to the principal direction of rolling except in the case of sections and narrow flats, i.e. up to and including 610 mm (24 in) wide.

Alternative Tensile Test Pieces

204 Tensile test pieces of other dimensions or of cylindrical form may be used, provided that the elongations comply with 205, and provided that the cross-sectional area is not less than 161 mm^2 (0·25 in^2).

Elongations in Tensile Test

205 (*a*) The required minimum elongations, E, are indicated in Table P 2.2. These elongations are based on test pieces having gauge lengths equal to 5,65 times the square root of the cross-sectional area, or 5 times the diameter.

(*b*) For test pieces having gauge lengths bearing other relationships to the cross-sectional area, the equivalent elongations shall be calculated from the following formula:—

$$E = \frac{n}{2}\left(\frac{Lo}{\sqrt{So}}\right)^{0,40}$$

where n = actual measured percentage elongation of test piece,

S_o = actual cross-sectional area of test piece,

L_o = actual gauge length of test piece,

E = equivalent percentage elongation for a test piece with a gauge length of $5{,}65\sqrt{S_o}$.

NOTE.—S_o and L_o may be in any consistent units.

(c) For the "standard" test piece (*see* 203) the minimum percentage elongations shall not be less than the following:—

Thickness	*Minimum Elongation*
6 mm (0·25 in)	... 0,68E
30 mm (1·2 in) and over	... 0,95E

where E is the specified minimum percentage elongation for a test piece with a gauge length of $5{,}65\sqrt{S_o}$. The elongations for thicknesses between 6 mm and 30 mm (0·25 and 1·2 in) may be obtained from the above by linear interpolation.

Bend Tests

206 The bend test shall consist in bending a strip or bar of the material until the ends are parallel to each other, and at a distance apart not exceeding three times the thickness or diameter of the strip or bar.

The strips shall have a width at least equal to the thickness but not less than 25 mm (1 in) and a thickness not less than that of the material tested, retaining the original rolled surfaces. The sharp edges of the strip may be removed by filing or machining, to a radius not exceeding 0,1 of the thickness of the strip.

When the power of the available testing machine is insufficient to bend a test piece of the full thickness, this latter may be reduced by machining from one face or by turning down a round bar provided that the final thickness or diameter is not less than 25 mm (1 in). Strips shall be so bent that the original rolled surface is on the tension side.

The strips shall be cut with their lengths transverse to the principal direction of rolling except in the case of sections and narrow flats, i.e. up to and including 610 mm (24 in) wide. The bending may be performed by pressure or by blows.

The bend test will be considered successful if no cracks or laminations appear.

Impact Tests

207 The impact test pieces shall be of the Charpy V-notch type machined to the dimensions and tolerances given in Table P 2.1. Standard test pieces 10 mm square shall be used except where the thickness of the material does not permit this size of test piece being prepared. In such cases the largest possible size of subsidiary test piece is to be prepared with the notch cut on the narrow face. Alternatively, for material of suitable thickness, the rolled surfaces may be retained so that the test piece width will be the full thickness of the material. The prescribed dimensions are to be carefully and systematically checked. The test pieces shall be cut with their longitudinal axes parallel to the final direction of rolling of the material. The notch shall be cut in a face of the test piece which was originally perpendicular to the rolled surface.

TABLE P 2.1

DIMENSIONS AND TOLERANCES FOR CHARPY V-NOTCH TEST PIECES

Dimensions		Nominal Dimension	Tolerance
Length		55 mm	±0,60 mm
Width ...	Standard	10 mm	±0,11 mm
	Subsidiary	7,5 mm	±0,11 mm
	,,	5,0 mm	±0,05 mm
Thickness		10 mm	±0,11 mm
Angle of notch		45°	±2°
Depth below notch ...		8 mm	±0,11 mm
Root radius		0,25 mm	±0,025 mm
Distance of notch from end of test piece		27,5 mm	±0,42 mm
Angle between plane of symmetry of notch and longitudinal axis of test piece		90°	±2°

The position of the notch shall not be nearer than 25 mm (1 in) to a flame-cut or sheared edge.

In the case of sections, the test pieces are to be cut from the thickest part.

The tests are to be carried out with the test pieces at a temperature carefully controlled to within ± 1 degC of the required temperature, on a Charpy impact machine of approved type installed in an approved manner having a gap of 40 mm, a striking velocity between 4,5 and 6 m/second, and a striking energy of not less than 15 kg m. The angle of the striking edge of the pendulum is to be 30° with the

edge rounded to a radius not exceeding 2 mm. The machine is to be periodically checked and calibrated on the lines indicated in P 112.

Alternative Types of Test

208 Other alternative types of test may be substituted for the Charpy V-notch impact test provided that equivalent standards of notch ductility can be established to the satisfaction of the Society.

Number of Tensile Tests

209 For each batch presented, one tensile test shall be made from one piece rolled from each cast unless the weight of finished material is greater than 40 000 kg (40 tons) in which case one extra test shall be made from each 40 000 kg (40 tons) or fraction thereof. Additional tests are to be made for every variation of 5 mm (0·20 in) in the thicknesses of pieces from the same cast.

Number of Bend Tests

210 One bend test piece is to be prepared from material adjacent to each tensile test piece.

Number of Impact Tests (where required)

211 Unless otherwise specified for a particular grade of steel, at least one piece is to be selected for impact testing from the thickest batch from each cast, unless the weight of finished material rolled from the cast is greater than 40 000 kg (40 tons) in which case one extra test will be made from a different piece from each 40 000 kg (40 tons) or fraction thereof, provided that the same procedures have been used in manufacture.

When plates of different widths are included in batches of the same thickness the widest plate is to be preferred for testing.

From each piece so selected, three impact tests as described in 207 shall be carried out. The average values obtained from these tests shall comply with the requirements. If, however, the average obtained fails to comply by an amount not exceeding 15 per cent of the required value, three additional test pieces from the same sample may be tested, and the results added to those previously obtained to form a new average, which must comply with the requirements.

Definitions

212 The term "piece" is to be understood to mean the rolled product from a single slab or from a single ingot if this is rolled directly into plates, bars or sections. The term "item" means any single plate, bar or section as delivered. The term "test piece" where it occurs means the sample of material which is actually tested.

Additional Tests before Rejection

213 (*a*) When the tensile or bend tests on the first piece selected in accordance with 209 and 210 fail to meet the requirements, two further tests of the same kind may be made from the same piece. If both these additional tests are satisfactory the piece and the remaining pieces from the same cast may be accepted.

(*b*) If the additional tests referred to in (*a*) are unsatisfactory the piece is to be rejected, but the remaining material from the same cast may be accepted provided that two of the remaining pieces selected in the same way are tested with satisfactory results.

(*c*) If the impact tests, carried out in accordance with 211 on the first piece selected, fail to meet the requirements the piece is to be rejected, but the remaining material from the same cast may be accepted provided that two of the remaining pieces, selected in the same way, are tested in the same way with satisfactory results.

(*d*) If any test piece fails because of faulty preparation or (in the case of a tensile test) because of fracturing outside the middle half of the gauge length, the defective test piece may at the Surveyor's discretion be discarded and replaced by an additional test piece from the same piece.

(*e*) At the option of the steelmakers, rejected material may be re-submitted after heat treatment or re-heat treatment or may be re-submitted as another grade of steel, and may then be accepted provided that the required tests are satisfactory.

Position of Samples for Testing

214 Except where otherwise specially agreed, the samples taken from the rolled material for the preparation of test pieces are to be cut from the end of the piece corresponding to the top end of the ingot. When the axis of the ingot is transverse to the length of the piece, either end may be selected but the sample should preferably be taken near to the edge corresponding to the top of the ingot.

Heat Treatment

215 Unless otherwise specified, or required by the conditions of approval of the process, the material may be presented in the "as rolled" or heat treated condition at the maker's option, subject to full compliance with the remainder of these Rules, and provided that the material which is presented in the normalised or otherwise heat treated condition is to be tested separately from material presented in the "as rolled" condition, even when all such material is from the same cast.

The sample of material from which test pieces are cut must be heat treated together with and in the same way as

TABLE P 2.2

Grade	A	B	C	D	E
1. Method of Manufacture	As P 102	As P 102	Process to be specially approved	Process to be specially approved	Process to be specially approved
2. Deoxidation	Any method (For rimmed steel see Note 1)	Any method except rimmed steel.	Fully killed, fine grain practice (Aluminium treated)	Any method except rimmed steel	Fully killed, fine grain practice (Aluminium treated)
3. Austenitic Grain Size (McQuaid-Ehn method) ASTM scale (*See* P 217)	—	—	5 or finer To be determined on each charge (*see* Note 4)	—	5 or finer To be determined on each charge
4. Chemical Composition (ladle analysis)					
Carbon	*See* Note 2	0,21% max. (*See* Notes 3 & 5)	0,23% max. (Note 5)	0,21% max. (Note 5)	0,18% max. (Note 5)
Manganese ...	*See* Note 2	0,80% min. (*See* Notes 3 & 5)	0,60% to 1,40% (Note 5)	0,60% to 1,40% (Note 5)	0,70% to 1,50% (Note 5)
Silicon	—	—	0,15% to 0,30%	0,35% max.	0,10% to 0,35%
Sulphur	0,05% max.	0,05% max.	0,05% max.	0,05% max.	0,05% max.
Phosphorus ...	0,05% max.	0,05% max.	0,05% max.	0,05% max.	0,05% max.
5. Tensile Test Tensile strength, kg/mm^2 ... ... (ton/in^2) ... ... (*See* P 112)	41 to 50 (26 to 32)	41 to 50 (26 to 32)	41 to 50 (26 to 32)	41 to 50 (26 to 32)	41 to 50 (26 to 32)
Elongation on $5{,}65\sqrt{So}$ % minimum (*See* P 205)	22%	22%	22%	22%	22%
6. Impact Test Test Temperature	—	—	—	0°C	−10°C
Minimum Energy Width of test piece				kg m / ft lb	kg m / ft lb
10 mm	—	—	—	4,8 / 35	6,2 / 45
7,5 mm	—	—	—	4,1 / 30	5,4 / 39
5,0 mm	—	—	—	3,5 / 25	4,6 / 33
(*See* Note 7)					Every plate to be tested
7. Bend Test	As P 206	As P 206	As P 206	As P 206	As P 206
8. Heat Treatment	*See* P 215	*See* P 215	Normalised over 33 mm (1·25 in) thick	*See* P 215	Normalised

NOTES—TABLE P 2.2

1. For Grade A, rimming steel may be accepted up to 12,5 mm (0·5 in) thick inclusive, provided that it is stated on the mill sheets to be rimming steel and is not excluded by the purchaser's order.

2. For Grade A in thicknesses over 12,5 mm (0·5 in) the manganese content shall not be less than 2,5 times the carbon content.

3. For Grade B, when the silicon content is 0,15 per cent or more (killed steel) the minimum manganese content may be reduced to 0,60 per cent.

4. For Grade C the determination of grain size may be alternatively substituted by impact tests as required for Grade D.

5. For Grades B, C, D and E, the sum of carbon content plus $\frac{1}{6}$ of the manganese content shall not exceed 0,40 per cent.

6. Grade C may be accepted as an alternative to Grade D subject to compliance with the impact test requirements of Grade D. In special circumstances impact tests may not be required.

7. Where non-standard subsidiary impact test pieces are used, the minimum value may be obtained by interpolation.

the material presented. Test specimens may not be separately heat treated in any way.

Chemical Analysis

216 The chemical composition shall be determined by the makers in an adequately equipped and competently staffed laboratory on samples taken from each ladle of each cast. The maker's analysis will be accepted subject to occasional checks if required by the Surveyors.

Austenitic Grain Size

217 The austenitic grain size where required is to be determined by the McQuaid-Ehn method from samples representative of each ladle of each cast. The grain size numbers indicated refer to the ASTM scale described in ASTM E112-63T, or any later ASTM specification which may supersede it.

Applications

218 For information regarding requirements for the application of different grades of steel, reference should be made to the following paragraphs:—

D 410, D 411, D 422, D 512, D 513, D 4008, D 4009, Sections D 70, D 71 and D 72.

Section 3

HIGHER TENSILE STEEL FOR HULL STRUCTURES

The following paragraphs do not constitute a complete specification for higher tensile steel for hull construction but are intended for the guidance of Steelmakers and Shipbuilders.

General

301 The requirements of P 1 and P 2 are to be complied with so far as they are applicable and as amended in the following paragraphs.

Approval of Steel

302 Full details of the method of manufacture including chemical composition, heat treatment and mechanical properties are to be submitted for approval. If considered necessary, tests are to be made on samples of steel manufactured in accordance with the proposed specification.

The steel should be capable of being fabricated and welded under shipyard conditions. When the carbon equivalent calculated from the ladle analysis and using the formula given below, is in excess of 0,45% approved low hydrogen higher tensile electrodes and preheating are to be used. When the carbon equivalent is not more than 0,45% approved low hydrogen higher tensile electrodes are to be used but preheating will not generally be required except under conditions of high restraint or low ambient temperature. When the carbon equivalent is not more than 0,41% any type of approved higher tensile electrodes may be used and preheating will not generally be required except as above.

Carbon equivalent C.E. =

$$C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}$$

This formula is only applicable to steels which are basically of the carbon-manganese type containing minor quantities of grain refining elements, for example, niobium, vanadium or aluminium, and the proposed use of low alloy steels will be subject to special consideration.

Number of Tests

303 The number of tests required will depend on the proposed chemical composition and heat treatment of the steel and will be agreed with the manufacturer at the time of approval or after a trial period of production.

The number of tests required, however, will not be less than:—

For Grades AH and DH steel one tensile test, one bend test and one set of three Charpy V-notch tests are to be made from one piece rolled from each cast unless the weight of finished material is greater than 40 000 kg (40 tons) in which case one extra set of tests is to be made from each 40 000 kg (40 tons) or fraction thereof. Additional tests are to be made for every variation of 5 mm (0·20 in) in the thicknesses of pieces from the same cast (*see also* footnote to 304 (f)).

For Grade EH steel one tensile test and one bend test is to be made as above and in addition one set of three Charpy V-notch tests are to be made from each piece (*see* P 212) provided all items cut from each piece are heat treated at the same time.

Mechanical Properties

304 (*a*) All test pieces are to be prepared in accordance with the requirements for mild steel as given in P 2.

(*b*) The tensile strength is to be within the limits given in the approved specification. The specified range between maximum and minimum is not to exceed 12,6 kg/mm^2 (8 ton/in^2).

(*c*) The yield stress is to be not less than the value given in the approved specification and, in any particular test is not to exceed 80% of the actual tensile strength. (*See also* 305).

(*d*) The percentage elongation on a gauge length of $5{,}65\sqrt{So}$ is to be not less than the value given in the approved specification.

(*e*) Bend Tests. The test pieces are to be bent cold without fracture. The diameter of the former and the angle of bend are to comply with the approved specification.

(*f*) The Charpy V-notch impact values are to be determined in accordance with P 207 and P 211. The percentage crystallinity, based on the original area is to be recorded for information.

GRADE	TEST TEMP.	MINIMUM ENERGY	
		kg m	ft lb
AH (For Grade A application)	0°C	2,765 (*see* Note)	20 (*see* Note)
DH (For Grade D application)	0°C	$4{,}84\frac{1}{\sqrt{k}}$	$35\frac{1}{\sqrt{k}}$
EH (For Grade E application)	−10°C	$6{,}22\frac{1}{\sqrt{k}}$	$45\frac{1}{\sqrt{k}}$

where $k = \dfrac{70{,}9}{Y + U}$ $\left(k = \dfrac{45}{Y + U}\ \text{British}\right)$

and Y = specified minimum upper yield stress or 0,5% proof stress in kg/mm^2 (ton/in^2) or $0{,}7U$ whichever is the less.

U = specified minimum tensile strength plus one half of the specified range, in kg/mm^2 (ton/in^2).

NOTE.—The necessity for impact testing of Grade AH plates will depend on the particular method of manufacture and will be decided when the specification is submitted for approval.

Determination of Yield Stress

305 When a beam type testing machine is being used the yield stress is to be calculated from the load immediately prior to a distinct drop of the beam.

When an indicator type of testing machine is being used the yield stress is to be calculated from the load immediately prior to a fall back in the movement of the pointer, or the load at a marked hesitation of the pointer.

Where no distinct yield is observed either the 0,2% proof stress or the 0,5% proof stress under load is to be determined.

The 0,2% proof stress is to be calculated from an accurate load/extension diagram by drawing a line parallel to the straight elastic portion and distant from it by an amount representing 0,2% of the extensometer gauge length. The point of intersection of this line with the plastic portion of the diagram represents the proof load, from which the 0,2% proof stress can be calculated.

The 0,5% proof stress under load is to be calculated from the load corresponding to a total extension of 0,5% of the original gauge length. This extension is to be measured either by the use of a suitable extensometer or by dividers.

In all cases the rate of increase of stress in the upper half of the elastic range and until the yield or proof load has been reached is not to be greater than 1 kg/mm^2/second ($0{\cdot}6$ ton/in^2/second). After reaching the yield or proof load the rate of straining may be increased to a maximum of 40% of the original gauge length per minute for the determination of the tensile strength.

Surface Inspection

306 Attention is drawn to P 104 and it is recommended that both surfaces of all plates be carefully inspected at the steelworks and the edges examined for laminations or other defects.

Freedom from Defects

307 If surface defects are repaired by welding (*see* P 201 (*c*)) the procedure shall be appropriate to the steel and a suitable heat treatment will be required.

Marking

308 Distinguishing marks are to be as required by P 106 and P 202 but the grade mark is to be followed by a letter "H" (as in 304 (f)). A large letter "H" is also to be painted near the brand marking in the appropriate colour given in P 202.

Section 4

STEEL RIVET BARS AND MANUFACTURED RIVETS

Testing of Material

401 All material from which rivets are manufactured is to be tested.

Rivets are not to be manufactured from steel in which the sulphur segregates and other non-metallic substances are concentrated in the core. To ensure this, a sulphur print is to be taken from the material of each cast, and where the weight of bars as rolled from one cast exceeds 10 000 kg (10 tons), additional sulphur prints may be taken.

Number of Tests

402 One tensile test piece is to be taken from each cast used for rivet bars; but where the weight of bars as rolled from one cast exceeds 10 000 kg (10 tons) an additional tensile test is to be made from each further 10 000 kg (10 tons) or portion thereof.

403 One dump test is to be made for each tensile test.

Tensile Test Pieces

404 Rivet bars may be tested in full section or may be machined to a convenient size provided the cross-sectional area is not less than 161 mm² (0·25 in²). Where a gauge length other than $5{,}65\sqrt{So}$ is used the equivalent elongation is to be calculated using the formula given in P 205.

Tensile Test

405 The tensile strength of steel rivet bars is to be within the limits of 41 and 50 kg/mm² (26 and 32 ton/in²) and the elongation on a gauge length of $5{,}65\sqrt{So}$ is to be not less than 26 per cent.

Dump Test

406 Short lengths, equal to twice their diameter, cut from the rivet bars shall, when cold, withstand without fracture being compressed to half their length.

Manufactured Rivets

407 Rivets selected by the Surveyor from the bulk are to withstand the tests described in 408 to 410.

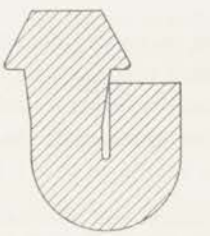


Fig. P 4.1

Fig. P 4.2

408 The rivet shanks are to be bent cold, and hammered until the two parts of the shank touch in the manner shown in Fig. P 4.1, without fracture on the outside of the bend.

409 The rivet heads are to be flattened, while hot, in the manner shown in Fig. P 4.2, without cracking at the edges. The heads are to be flattened until their diameter is 2,5 times the diameter of the shank.

410 In the case of steel rivets, samples are to be selected by the Surveyor for examination by means of sulphur prints, to ensure that the material is free from marked central segregation.

Section 5

STEEL CASTINGS

Scope

501 Cast steel sternframes, rudder frames, rudder stocks, propeller shaft brackets and other steel castings intended for use in hull construction are to be manufactured and tested in accordance with the requirements of this section.

Where it is proposed to use low alloy steel castings, particulars of the chemical composition, mechanical properties and heat treatment are to be submitted for approval. These castings are to be tested and accepted on the basis of the approved specification and such other tests as may be considered necessary.

Manufacture

502 All castings are to be made at foundries approved by the Committee.

Steel is to be manufactured in accordance with P 102.

All flame cutting, scarfing or arc-air gouging to remove surplus metal is to be completed before the final heat treatment of the casting and preheating is to be applied where necessary. The affected parts are to be ground smooth.

Chemical Composition

503 Castings are to be made in carbon or carbon manganese steel. The chemical composition of ladle samples is to comply with the following:—

Carbon	... 0,23% max.
Silicon...	... 0,60% max.
Manganese	... 1,60% max. but not less than 3 times the actual carbon content.
Sulphur	... 0,050% max.
Phosphorus	... 0,050% max.

Residual elements, nickel, chromium, molybdenum, copper:—total not to exceed 0,8%.

Heat Treatment

504 Steel castings are to be heat treated by any of the following methods:—

(1) Full annealing by heating to a temperature within the range 850°C to 950°C followed by cooling slowly in the furnace in a uniform manner.

(2) Normalising by heating to a temperature within the range 850°C to 950°C followed by cooling in air and, where appropriate, subsequently tempering at a temperature of not less than 620°C.

(3) A combination of both of these treatments, e.g. annealing or homogenising at a relatively higher temperature as a preliminary refining treatment to subsequent normalising and tempering as in (2).

Heat treatment is to be carried out in properly constructed furnaces which are efficiently maintained and have adequate means for temperature control and are fitted with pyrometers which measure the temperature of the furnace charge. The furnace dimensions must permit the whole item being uniformly heated to the necessary temperature.

Test Material

505 (*a*) Test material for the preparation of at least one tensile and one bend test piece is to be cast attached to each casting at positions agreed between the manufacturer and Surveyor. When larger castings are made from more than one cast of steel, or are of complex design, the number of tests is to be agreed with the Surveyor.

The test material is not to be cut from the castings until heat treatment has been completed nor until the test material has been stamped by the Surveyor.

(*b*) The tensile test piece is to be machined to a diameter of 14 mm (0·564 in) with a gauge length of 70 mm (2·80 in). Alternatively, at the request of the manufacturer, test pieces with other gauge lengths or larger diameters may be used.

(*c*) Bend test pieces are to be machined to either a rectangular section 25 mm (1 in) wide by 20 mm (0·75 in) thick or a round section 25 mm (1 in) diameter. The sharp edges of rectangular section test pieces may be removed by suitable mechanical means to a radius not exceeding 1,5 mm (0·0625 in).

Mechanical Properties

506 (*a*) All tests are to be carried out in the presence of the Surveyor.

(*b*) The tensile strength is to be between the limits of 41 and 55 kg/mm^2 (26·0 and 35·0 ton/in^2).

Elongation values are to be reported on a gauge length equal to $5{,}65\sqrt{So}$, where So is the cross-sectional area of the test piece. The elongation is to be not less than 20% and where the actual gauge length used is other than $5{,}65\sqrt{So}$ the equivalent elongation is to be calculated using the formula or factors given in P 205 or Q 202.

The bend test piece is to withstand being bent through an angle of 120° round a former having a diameter not greater than 60 mm (2·25 in).

(*c*) If for any reason after testing as above, a casting is given a further full annealing or normalising heat treatment, e.g. after weld repairs, then the original tests are to be disregarded and further complete mechanical tests are to be made.

(*d*) Where either the tensile test or the bend test, or both, fail to meet the specified requirements, and the Surveyor considers the fractured test piece or test pieces, or the results obtained therefrom, do not fairly represent the quality of the casting, two further test pieces of the same type are to be taken for each original test that failed. In such cases the quality of the casting is to be judged by the result of the re-tests and not by the original test or tests which failed.

When one or both of the retests fail then the casting is to be rejected.

(*e*) At the option of the manufacturer, when tests on a casting fail to meet the specified requirements, the casting may be re-heat treated and re-submitted for test provided it is not heated above the upper critical temperature more than three times, i.e. original and two re-treatments.

Inspection

507 (*a*) The manufacturer is to make any tests necessary to prove the casting technique for prototype castings.

When castings are produced in regular quantities the manufacturer is to make periodical examinations to verify the continued efficiency of the manufacturing technique and the Surveyor is to be given the opportunity to witness these tests.

(*b*) All castings are to be cleaned and adequately prepared for inspection. Suitable methods include pickling, caustic cleaning, wire brushing, local grinding, shot or sand blasting. Before examination the surfaces must not be hammered, peened or treated in any way which may obscure defects.

(*c*) All important castings are to be examined by magnetic particle methods in at least all areas containing changes of section and where surplus metal has been removed by flame cutting, scarfing or arc-air gouging. The techniques employed are to be in accordance with recognised good practice, including any necessary surface preparation and are to be carried out by competent personnel using reliable and efficiently maintained equipment. The

term "magnetic particle examination" is intended to imply inspection for surface flaws using suitable magnetic methods but when this is not practicable a suitable dye penetrant method may be used instead.

(*d*) In all cases, in order to determine the soundness of the castings, supplementary examinations by radiography, ultrasonic, or other approved methods of non-destructive testing may be requested. When such examination is to be carried out it should be at positions, mutually agreed by the Surveyor and manufacturer, where experience shows that cavities, contraction cracks, or other defects are most likely to occur.

(*e*) The Surveyor is to examine each large casting before final acceptance at the foundry.

Repair of Defects

508 (*a*) When defects are found in a casting these are to be removed by grinding or by chipping and grinding. Flame scarfing or arc-air gouging may also be used provided that preheating is employed when necessary and that the surfaces of the resulting depressions are subsequently ground smooth. Complete elimination of the defective material is to be proved by magnetic particle tests. Shallow grooves or depressions resulting from the removal of defects can, at the Surveyor's discretion, be accepted provided these are blended by grinding.

(*b*) Proposals to repair a defective casting by welding are to be submitted to the Surveyor before work is commenced. The Surveyor is to satisfy himself that the number and size of the defects are such that the casting can be efficiently repaired.

When it has been agreed that the casting can be repaired it is to be proved by suitable methods of inspection that the defects have been completely removed and the defective area is to be prepared in a form suitable for welding. All castings in alloy steels and, if necessitated by the shape, castings in carbon or carbon manganese steels are to be given a preliminary refining heat treatment prior to carrying out weld repairs. Such castings are also to be pre-heated to a suitable temperature. An electric arc welding process is to be used and the weld deposit is to have properties similar to and in no way inferior to the parent metal. Welding of the affected parts is to be undertaken by a procedure the essential elements of which have been tested previously by the manufacturers and approved by the Surveyor. The welding is to be done under cover in positions free from draughts and adverse weather conditions by competent welders with adequate supervision.

After welding the castings are to be suitably heat treated either by annealing, normalising and tempering or stress relieving at a temperature of not less than 600°C. The type of heat treatment employed will be dependent on the size, position and nature of the defects. On completion of heat treatment, the weld repairs and adjacent metal are to be ground smooth and proved by a suitable method of magnetic particle inspection. Subject to the approval of the Surveyor, a local stress relieving heat treatment may be carried out where the area involved is small and machining of the casting has reached an advanced stage.

Identification

509 Before any casting is finally accepted it is to be clearly marked by the manufacturer in at least one place with the following particulars:—

(i) "L.R." or "Lloyd's" and the abbreviated name of the Society's local office.

(ii) Identification mark which will enable the full history of the casting to be traced.

(iii) Date of final inspection.

(iv) Personal stamp of Surveyor responsible for final inspection.

Documentation

510 The manufacturer is to supply the Surveyor with a written statement giving the steelmaking process, cast number, cast analysis, mechanical test results and general details of heat treatment together with full particulars of the purchaser, order number and description.

When repairs have been made by welding the manufacturer may be requested to provide the Surveyor with a statement and/or sketch detailing the extent and location of the repairs together with details of the heat treatment carried out at all stages.

Section 6

STEEL FORGINGS

Scope

601 Forgings for sternframes, rudder frames, rudder stocks, propeller shaft brackets and other steel forgings intended for use in hull construction are to be manufactured and tested in accordance with the requirements of this section. These requirements are also applicable to rolled slabs or billets used as a substitute for forgings.

Where it is proposed to use low alloy steel forgings, particulars of the chemical composition, mechanical properties and heat treatment are to be submitted for approval. These forgings are to be tested and accepted on the basis of the approved specification and such other tests as may be considered necessary.

Manufacture

602 (*a*) The steel is to be manufactured in accordance with P 102.

When forgings are made from ingots, or from blooms forged from ingots, the ingots are to be cast in metal moulds with the larger cross-section uppermost and with efficient feeder heads. The forgings are to be gradually and uniformly hot worked and are to be brought as nearly as possible to the finished shape and size. Where practicable they are to be worked so as to cause metal flow in the most favourable direction having regard to the mode of stressing in service. Adequate top and bottom discards are to be made to ensure freedom from piping and harmful segregations in the finished forgings.

Unless otherwise approved the maximum sectional area of any part of a forging (as forged) is not to exceed:—

$\frac{1}{3}$A where the length of any section is greater than its diameter,

$\frac{2}{3}$A where the length of any section is less than its diameter (e.g. a collar).

A is the average sectional area of the ingot or of the ingot after upsetting if such an operation is involved.

(*b*) When forgings are made from rolled products the maximum sectional area of a forging (as forged) is not to exceed:—

(i) when made from products rolled from ingots cast large end uppermost with efficient feeder heads,

$\frac{1}{4}$A where the length of any section is greater than its diameter,

or $\frac{1}{2}$A where the length of any section is less than its diameter (e.g. a collar),

or (ii) when made from products rolled from other types of ingots,

$\frac{1}{6}$A where the length of any section is greater than its diameter,

or $\frac{1}{3}$A where the length of any section is less than its diameter (e.g. a collar),

A is the average cross-sectional area of the original ingot.

(*c*) The shaping of forgings or rolled products by flame cutting is to be undertaken in accordance with a procedure approved by the Surveyor. Pre-heating is to be employed when necessitated by the thickness and on completion of shaping the forgings or rolled products may require to be heat treated in accordance with 604 (*b*).

Chemical Composition

603 (*a*) Forgings to which structural items are to be attached by welding or which are intended for parts of a fabricated component are to be made in carbon or carbon-manganese steel. The chemical composition of ladle samples is to comply with the following:—

Carbon	... 0,23% max.
Silicon...	... 0,15–0,50%
Manganese	... 0,30–1,60% but not less than 3 times the actual carbon content for components which are not given a post-weld heat treatment.
Sulphur	... 0,050% max.
Phosphorus	... 0,050% max.

Residual elements, nickel, chromium, molybdenum, copper:—total not to exceed 0,8%.

(*b*) For forgings not intended for welding the chemical composition of ladle samples is to comply with the following:—

Carbon	... 0,30% max.
Silicon...	... 0,15–0,50%
Manganese	... 0,30–1,60%
Sulphur	... 0,050% max.
Phosphorus	... 0,050% max.

Residual elements, nickel, chromium, molybdenum, copper:—total not to exceed 0,8%.

(*c*) Rolled products and forgings made from rolled products may have a silicon content of less than 0,15% i.e. semi-killed steel, provided that the cross-sectional area does not exceed 195 cm² (30 in²).

Heat Treatment

604 (*a*) All forgings and rolled products intended as a substitute for forgings are to be heat treated by any of the following methods:—

(1) Full annealing by heating to a temperature within the range 850°C to 950°C followed by cooling slowly in the furnace in a uniform manner.

or (2) Normalising by heating to a temperature within the range 850°C to 950°C followed by cooling in air and subsequently tempering at a temperature of not less than 580°C if the diameter of the body of the forging is equal to or greater than 900 mm (35 in). Smaller diameter forgings may also be tempered after the normalising heat treatment at the option of the forgemaster.

(*b*) If flame cutting or shaping is carried out subsequent to the above heat treatment, a further normalising or a stress relieving heat treatment may be required, depending on the extent of flame cutting and whether sufficient material is subsequently to be machined from the flame cut surfaces.

When a stress relieving heat treatment is required, this is to be carried out in the temperature range of 600°C to 650°C.

(*c*) Heat treatment is to be carried out in properly constructed furnaces which are efficiently maintained and have adequate means for temperature control and are fitted with pyrometers which measure the temperature of the furnace charge. The furnace dimensions must permit the whole item being uniformly heated to the necessary temperature.

(*d*) Rolled products intended for forging stock and subsequent hot working do not require to be supplied in the heat treated condition.

Test Material

605 (*a*) Test material is to be provided integral with the forging and with a cross-sectional area of not less than that of the main part of the forging. At least one tensile and one bend test are to be taken from each forging, except where both the weight and length are in excess of 4000 kg (4 tons) and 3 m (10 ft) respectively, when tensile and bend tests are to be taken from each end. These limits refer to the "as forged" weight and length but excluding the test material.

(*b*) When a forging is subsequently divided into a number of items all of which are heat treated together in the same furnace then for test purposes this may be considered as one forging and the test material required is to be related to the total length and weight of the original forging.

Where a number of separate forgings are made from one cast of steel and are heat treated together in one furnace then a system of batch testing may be adopted. The number of tests required and the method of providing the test material is to be agreed with the Surveyor.

(*c*) For rolled products at least one tensile and one bend test piece are to be taken from each piece (*see* P 212) except where these are intended for forging stock and will subsequently be hot worked.

(*d*) Tensile and bend test pieces are to be cut longitudinally or parallel to the direction of principal grain flow. Where test pieces cannot reasonably be provided in the longitudinal direction they may be cut in a transverse direction. The test material is not to be cut from the forgings until heat treatment has been completed nor until the test material has been stamped by the Surveyor.

(*e*) The tensile test piece is to be machined to a diameter of 14 mm (0·564 in) with a gauge length of 70 mm (2·80 in). Alternatively, at the request of the manufacturer, test pieces with other gauge lengths or larger diameters may be used.

Bend tests are to be machined to a rectangular section 25 mm (1 in) wide and 20 mm (0·75 in) thick. The sharp edges of the test pieces may be removed by suitable mechanical means to a radius not exceeding 1,5 mm (0·0625 in).

Mechanical Properties

606 (*a*) All tests are to be carried out in the presence of the Surveyor.

(*b*) The tensile strength is to be between the limits of 44 and 54 kg/mm² (27·9 and 34·3 ton/in²).

Elongation values are to be reported on a gauge length equal to $5{,}65\sqrt{So}$, where So is the cross-sectional area of the test piece. The elongation is to be not less than 22% for tests in the longitudinal direction and not less than 18% for tests in the transverse direction. Where the actual gauge length used is other than $5{,}65\sqrt{So}$ the equivalent elongation is to be calculated using the formula or factors given in P 205 or Q 202.

Bend test pieces which are cut in a longitudinal direction are to withstand being bent without fracture through an angle of 180° round a former having a diameter not greater than 12,5 mm (0·5 in). For test pieces cut in a transverse direction the diameter of the former is to be not greater than 25 mm (1 in).

(*c*) Where either the tensile test or the bend test, or both, fail, and the Surveyor considers the fractured test piece or test pieces, or the results obtained therefrom, do not fairly represent the quality of the forging then the procedure given in P 506 (d) or (e) may be adopted.

Inspection

607 The Surveyor is to examine each forging before final acceptance at the forge.

Repair of Defects

608 (*a*) When defects are found in a forging these are to be removed by grinding or by chipping and grinding. Complete elimination of the defective material is to be proved by magnetic particle tests. Shallow grooves or depressions resulting from the removal of defects can be accepted at the Surveyor's discretion provided they are blended by grinding.

(*b*) Repair by welding is not generally permitted but special consideration will be given to such repairs when they are of a minor nature and in areas of low working stresses. Proposals are to be submitted to the Surveyor before work is commenced and the Surveyor is to satisfy himself that the number and size of the defects are such that the forgings can be efficiently repaired.

(*c*) When it has been agreed that the forging can be repaired it is to be proved by suitable methods of inspection that the defects have been completely removed and the defective area is to be prepared in a form suitable for welding. An electric arc welding process is to be used and the weld deposit is to have properties similar to and in no way inferior to the parent metal. Welding of the affected parts is to be undertaken by a procedure the essential elements of which have been tested previously by the manufacturer and approved by the Surveyor. The welding is to be done under cover in positions free from draughts and adverse weather conditions by competent welders with adequate supervision.

After welding the forgings are to be suitably heat treated either by annealing, normalising and tempering or stress relieving at a temperature of not less than 600°C. The type of heat treatment employed will be dependent on the size, position and nature of the defects. On completion of heat treatment, the weld repairs and adjacent metal are to be ground smooth and proved by a suitable method of magnetic particle inspection.

Identification

609 Forgings are to be identified in the same manner as for steel castings (*see* P 509).

Documentation

610 The manufacturer is to supply the information required as for steel castings (*see* P 510).

When repairs have been made by welding the manufacturer is to provide a written statement and/or sketch detailing the extent and location of the repairs together with details of the heat treatment carried out at all stages.

Section 7

STEEL ANCHORS

Process of Manufacture

701 Forged steel anchor heads and shanks are to be manufactured and tested in accordance with the relevant requirements of P 6 except that heat treatment need only be carried out when the weight of the forging exceeds 3000 kg (3 tons).

Cast steel anchor heads and shanks are to be manufactured and tested in accordance with the relevant requirements of P 5 except that where more than one anchor casting is made from the same cast, only one tensile and one bend test piece need be taken provided all the castings are heat treated in the same batch and that the weight of the cast is 3000 kg (3 tons) or less. Additional tests are to be taken when the cast is in excess of this weight.

702 Each important part of an anchor is to be plainly marked by the maker with the words "forged ingot steel" or "heat treated cast steel" as the case may be (or simply "forged steel" or "cast steel").

703 Steel anchor shackles are to be made of forged steel or cast steel as specified in 701, but need not be submitted to the test requirements of P 5 and P 6.

Proof Tests of Anchors

704 Anchors weighing more than 76 kg (168 lb) inclusive of stock, are to be tested at a proving establishment recognised by the Committee (*see* D 3420). When the (United Kingdom) Anchors and Chain Cables Act applies* the anchors are to be tested at a Licensed Proving House in the United Kingdom.

*NOTE.—The Anchors and Chain Cables Act, 1899, applies to anchors bought or sold in the United Kingdom for use on a British ship.

705 The test load is to be as given in Table P 7.1A, or Table P 7.1B if the Anchors and Chain Cables Act applies.

The weight to be used in the Table is:—

(a) for stockless anchors—the total weight of the anchor,

(b) for stocked anchors—the weight of the anchor excluding the stock,

(c) for high holding power anchors (*see* D 3412)—a nominal weight equal to 1,33 times the actual total weight of the anchor.

TABLE P 7.1A—PROOF TESTS FOR ANCHORS

Weight of Anchor (See P 705)	Proof Test Load	Weight of Anchor (See P 705)	Proof Test Load	Weight of Anchor (See P 705)	Proof Test Load	Weight of Anchor (See P 705)	Proof Test Load	Weight of Anchor (See P 705)	Proof Test Load	Weight of Anchor (See P 705)	Proof Test Load
kg	kg	kg	kg	kg	kg	kg	kg	kg	kg	kg	kg
50	2370	500	11 800	2000	35 600	4500	63 400	7000	81 300	15 000	117 700
55	2570	550	12 700	2100	36 900	4600	64 300	7200	82 600	15 500	119 500
60	2760	600	13 500	2200	38 300	4700	65 100	7400	83 800	16 000	120 900
65	2950	650	14 300	2300	39 600	4800	65 800	7600	85 000	16 500	122 200
70	3130	700	15 200	2400	40 900	4900	66 600	7800	86 100	17 000	123 500
75	3300	750	16 100	2500	42 200	5000	67 400	8000	87 000	17 500	124 700
80	3460	800	16 900	2600	43 500	5100	68 200	8200	88 100	18 000	125 900
90	3700	850	17 800	2700	44 700	5200	69 000	8400	89 200	18 500	127 000
100	3990	900	18 600	2800	45 900	5300	69 800	8600	90 300	19 000	128 000
120	4520	950	19 500	2900	47 100	5400	70 500	8800	91 400	19 500	129 000
140	5000	1000	20 300	3000	48 300	5500	71 300	9000	92 400	20 000	130 000
160	5430	1050	21 200	3100	49 400	5600	72 000	9200	93 400	21 000	131 000
180	5850	1100	22 000	3200	50 500	5700	72 700	9400	94 400	22 000	132 000
200	6250	1150	22 800	3300	51 600	5800	73 500	9600	95 300	23 000	133 000
225	6810	1200	23 600	3400	52 700	5900	74 200	9800	96 200	24 000	134 000
250	7180	1250	24 400	3500	53 800	6000	74 900	10 000	97 100	25 000	135 000
275	7640	1300	25 200	3600	54 800	6100	75 500	10 500	99 300	26 000	136 000
300	8110	1350	26 000	3700	55 800	6200	76 200	11 000	101 500	27 000	137 000
325	8580	1400	26 700	3800	56 800	6300	76 900	11 500	103 600	28 000	138 000
350	9050	1450	27 500	3900	57 800	6400	77 500	12 000	105 700	29 000	139 000
375	9520	1500	28 300	4000	58 800	6500	78 200	12 500	107 800	30 000	140 000
400	9980	1600	29 800	4100	59 800	6600	78 800	13 000	109 900	31 000	141 000
425	10 500	1700	31 300	4200	60 700	6700	79 400	13 500	111 900		
450	10 900	1800	32 700	4300	61 600	6800	80 100	14 000	113 900		
475	11 400	1900	34 200	4400	62 500	6900	80 700	14 500	115 900		

or in British units:—

TABLE P 7.1A—PROOF TESTS FOR ANCHORS

Weight of Anchor (*See* P 705)	Proof Test Load	Weight of Anchor (*See* P 705)	Proof Test Load	Weight of Anchor (*See* P 705)	Proof Test Load	Weight of Anchor (*See* P 705)	Proof Test Load	Weight of Anchor (*See* P 705)	Proof Test Load	Weight of Anchor (*See* P 705)	Proof Test Load
Cwt	Tons	Cwt	Tons	Cwt	Tons	Cwt	Tons	Cwt	Tons	Cwt	Tons
1	2·37	19	19·44	58	46·9	108	70·1	158	85·8	300	117·0
1¼	2·85	20	20·28	60	48·1	110	70·8	160	86·3	310	118·0
1½	3·27	21	21·12	62	49·2	112	71·5	162	86·9	320	120·0
1¾	3·65	22	21·92	64	50·2	114	72·3	164	87·4	330	121·0
2	3·98	23	22·74	66	51·3	116	73·0	166	88·0	340	122·0
2½	4·63	24	23·48	68	52·4	118	73·7	168	88·5	350	123·0
3	5·18	25	24·33	70	53·4	120	74·3	170	89·0	360	124·0
3½	5·70	26	25·12	72	54·5	122	75·0	172	89·6	370	125·0
4	6·20	27	25·87	74	55·5	124	75·7	174	90·1	380	126·0
4½	6·68	28	26·52	76	56·5	126	76·3	176	90·6	390	127·0
5	7·14	29	27·46	78	57·5	128	77·0	178	91·2	400	128·0
5½	7·61	30	28·25	80	58·5	130	77·6	180	91·8	420	129·0
6	8·07	32	29·75	82	59·4	132	78·2	185	92·9	440	130·0
7	9·03	34	31·13	84	60·3	134	78·9	190	94·0	460	131·5
8	9·95	36	32·53	86	61·2	136	79·5	195	95·1	480	132·5
9	10·85	38	34·10	88	62·1	138	80·1	200	96·5	500	133·5
10	11·76	40	35·45	90	63·0	140	80·7	210	99·0	520	134·5
11	12·65	42	36·79	92	63·9	142	81·4	220	101·0	540	135·5
12	13·44	44	38·11	94	64·6	144	82·0	230	103·0	560	136·5
13	14·25	46	39·27	96	65·4	146	82·6	240	105·0	580	137·5
14	15·16	48	40·75	98	66·2	148	83·2	250	107·0	600	138·5
15	16·04	50	42·1	100	67·0	150	83·8	260	109·0	620	139·5
16	16·83	52	43·3	102	67·8	152	84·3	270	111·0		
17	17·72	54	44·5	104	68·6	154	84·8	280	113·0		
18	18·55	56	45·7	106	69·3	156	85·3	290	115·0		

TABLE P 7.1B—PROOF TESTS FOR ANCHORS

(Subject to Anchors and Chain Cables Act.)

Weight of Anchor (*See* P 705)	Proof Test Load	Weight of Anchor (*See* P 705)	Proof Test Load	Weight of Anchor (*See* P 705)	Proof Test Load	Weight of Anchor (*See* P 705)	Proof Test Load	Weight of Anchor (*See* P 705)	Proof Test Load	Weight of Anchor (*See* P 705)	Proof Test Load
kg	kg	kg	kg	kg	kg	kg	kg	kg	kg	kg	kg
75	4000	540	12 750	1200	24 000	3700	56 050	6200	76 600	8700	91 000
80	4100	560	13 150	1300	25 700	3800	57 050	6300	77 250	8800	91 500
90	4300	580	13 550	1400	27 250	3900	58 050	6400	77 850	8900	92 000
100	4550	600	13 950	1500	28 750	4000	58 950	6500	78 500	9000	92 500
120	4950	620	14 300	1600	30 250	4100	59 800	6600	79 100	9100	93 000
140	5350	640	14 650	1700	31 750	4200	60 800	6700	79 750	9200	93 500
160	5700	660	15 000	1800	33 250	4300	61 800	6800	80 350	9300	94 000
180	6100	680	15 300	1900	34 600	4400	62 750	6900	81 000	9400	94 500
200	6450	700	15 700	2000	35 950	4500	63 550	7000	81 600	9500	95 000
220	6850	720	16 050	2100	37 300	4600	64 500	7100	82 200	9600	95 500
240	7250	740	16 400	2200	38 750	4700	65 300	7200	82 850	9700	96 000
260	7600	760	16 750	2300	40 050	4800	66 250	7300	83 500	9800	96 500
280	7950	780	17 100	2400	41 300	4900	67 000	7400	84 100	9900	97 000
300	8300	800	17 450	2500	42 550	5000	67 750	7500	84 750	10 000	97 500
320	8700	820	17 800	2600	43 800	5100	68 500	7600	85 350	10 500	99 800
340	9100	840	18 150	2700	45 050	5200	69 250	7700	85 900	11 000	101 950
360	9500	860	18 500	2800	46 200	5300	70 000	7800	86 450	11 500	103 950
380	9850	880	18 800	2900	47 450	5400	70 750	7900	86 950	12 000	105 900
400	10 200	900	19 100	3000	48 550	5500	71 500	8000	87 450	12 500	107 900
420	10 600	920	19 400	3100	49 700	5600	72 250	8100	88 000	13 000	109 900
440	11 000	940	19 750	3200	50 800	5700	73 000	8200	88 500	13 500	111 900
460	11 400	960	20 100	3300	51 800	5800	73 750	8300	89 000	14 000	113 900
480	11 700	980	20 450	3400	52 800	5900	74 500	8400	89 500	14 500	115 900
500	12 050	1000	20 800	3500	54 050	6000	75 250	8500	90 000	15 000	117 900
520	12 400	1100	22 550	3600	55 050	6100	76 000	8600	90 500	15 500	119 900

The weight given in the above Table is either for stockless anchors or for stocked anchors without the stock.
For intermediate weights the test may be obtained by interpolation.
For high holding power anchors the weight to be used in the Table is to be that of the actual anchor increased by one-third.

or in British units:—

TABLE P 7.1B—PROOF TESTS FOR ANCHORS

(Subject to Anchors and Chain Cables Act.)

Weight of Anchor (See P 705)	Proof Test Load	Weight of Anchor (See P 705)	Proof Test Load	Weight of Anchor (See P 705)	Proof Test Load	Weight of Anchor (See P 705)	Proof Test Load	Weight of Anchor (See P 705)	Proof Test Load	Weight of Anchor (See P 705)	Proof Test Load
Cwt	Tons	Cwt	Tons	Cwt	Tons	Cwt	Tons	Cwt	Tons	Cwt	Tons
1	3·40	26	25·65	51	43·00	76	56·75	101	67·65	126	76·65
2	4·50	27	26·40	52	43·65	77	57·25	102	68·00	127	76·95
3	5·50	28	27·15	53	44·25	78	57·65	103	68·40	128	77·25
4	6·40	29	27·90	54	44·75	79	58·15	104	68·75	129	77·60
5	7·40	30	28·65	55	45·40	80	58·50	105	69·15	130	77·90
6	8·25	31	29·40	56	46·00	81	59·00	106	69·50	140	81·00
7	9·25	32	30·15	57	46·65	82	59·50	107	69·90	150	84·15
8	10·15	33	30·90	58	47·25	83	60·00	108	70·25	160	86·75
9	11·15	34	31·65	59	47·75	84	60·50	109	70·65	170	89·25
10	12·00	35	32·40	60	48·40	85	61·00	110	71·00	180	91·75
11	12·90	36	33·15	61	48·90	86	61·50	111	71·40	190	94·25
12	13·90	37	33·75	62	49·50	87	61·90	112	71·75	200	96·75
13	14·75	38	34·50	63	50·00	88	62·25	113	72·15	210	98·95
14	15·65	39	35·15	64	50·50	89	62·75	114	72·50	220	101·05
15	16·50	40	35·75	65	51·00	90	63·25	115	72·90	230	103·00
16	17·40	41	36·50	66	51·50	91	63·65	116	73·25	240	105·00
17	18·25	42	37·15	67	52·15	92	64·00	117	73·65	250	107·00
18	19·00	43	37·90	68	52·65	93	64·50	118	74·00	260	109·00
19	19·90	44	38·65	69	53·25	94	65·00	119	74·40	270	111·00
20	20·75	45	39·25	70	53·75	95	65·40	120	74·75	280	113·00
21	21·65	46	39·90	71	54·25	96	65·75	121	75·10	290	115·00
22	22·40	47	40·50	72	54·75	97	66·15	122	75·40	300	117·00
23	23·15	48	41·15	73	55·25	98	66·50	123	75·70	—	—
24	23·90	49	41·75	74	55·75	99	66·90	124	76·00	—	—
25	24·75	50	42·40	75	56·25	100	67·25	125	76·35	—	—

The weight given in the above Table is either for stockless anchors or for stocked anchors without the stock.
For intermediate weights the test may be obtained by interpolation.
For high holding power anchors the weight to be used in the Table is to be that of the actual anchor increased by one-third.

Table P 7.1B

Section 8

CHAIN CABLES AND STEERING CHAINS

Note.—For list of approved manufacturers see Appendix following Chapter Q.

Scope

801 Provision is made for the testing of bar material intended for the manufacture of welded chain, material tests for drop forged and cast links and the testing of completed chain, attachment links and shackles. Chain cables or steering gear chains may be of any one of the grades shown in Table P 8.1.

Method of Manufacture

802 The methods of manufacture of Grades 1(a) and 1(b) do not require to be approved but rimming steel should not be used.

803 The steel used for the manufacture of Grades U 1, U 2 and U 3 chain cable is to be made in accordance with P 102. Rimming steel is not acceptable.

The links may be made by the flash-butt or other approved welding process or they may be steel castings or drop forgings. The method of manufacture and the chemical composition are to be approved and the requisite preliminary tests carried out. Approval tests for higher grades cover lower grades (up to the same diameter) provided the method of manufacture and heat treatment are generally the same.

Chemical Composition

804 The chemical composition is to comply with the manufacturer's approved specification and is to be determined in accordance with P 216.

Heat Treatment

805 (a) Bar material intended for the manufacture of chain may be supplied in the "as rolled" or heat treated condition in accordance with the requirements of the chain maker.

(b) Heat Treatment of Completed Chain. Grade U 1 chain cable may either be supplied in the "as welded" condition or may be normalised. If supplied in the "as welded" condition additional breaking tests will be required as detailed in Table P 8.2.

Grade U 2(a) cable is to be normalised. Grade U 2(b) cast steel cable is to be normalised, or may, at option of the manufacturer, be hardened by quenching and tempered.

Grade U 3 cable is to be normalised, normalised and tempered, or hardened by quenching and tempered.

In all cases heat treatment is to be carried out prior to the proof loading and breaking tests of the completed chains and links.

806 For certain types of drop forged cable the requirements of 805, and the procedure for material tests, will be specially considered.

Test Material and Test Pieces

807 (a) For Grades U 1 and U 2(a) the bar material may be tested either in the "as rolled" condition or after heat treatment in full size and in a manner simulating the heat treatment applied to the finished cable. For Grade U 3(a) the test material is to be heat treated in full size and in a manner simulating the treatment applied to the finished chain.

Test material representative of cast or drop forged links is to be heat treated along with and in the same manner as the completed cable (*see also* 806).

(b) For material tests one set of tests as required by Table P 8.1 is to be taken from every 10 tonnes (tons) or part of 10 tonnes (tons) of each dimension from the same cast where the bar diameter does not exceed 60 mm (2·36 in). Where the diameter exceeds 60 mm (2·36 in) but does not exceed 80 mm (3·15 in) they are to be taken from every 15 tonnes (tons) and for diameters exceeding 80 mm (3·15 in) from every 25 tonnes (tons).

From completed chain, 3-link samples are to be selected by the Surveyor for the breaking tests specified in 810(b). In addition, for grade U 3, extra links are required for mechanical tests specified in 810(c).

(c) Tensile test pieces may be either the full section "as rolled" or of the round proportional type provided the cross-sectional area is not less than 161 mm^2 (0·25 in^2), and the machining is in accordance with a recognised National Standard. For machined test pieces the diameter of the reduced portion and the position of the test piece relative to the bar cross-section are to be selected so that the test piece is representative of the average properties of the bar.

For cast or drop forged links test pieces of the machined type are to be used.

The gauge length is generally to be five times the diameter of the test portion. For other gauge lengths the equivalent elongations are to be determined in accordance with P 205(b). For Grade U 3(a) cable the minimum reduction of area= 40 per cent, for Grade U 3(b)=35 per cent.

Bend test pieces may be either the full section as rolled, or may be machined to 25 mm (1 in) diameter, or rectangular cross section 25×19 mm (1×0·75 in).

Impact test pieces are to be of the Charpy V-notch type in accordance with P 207. They are to be cut as shown in Fig. P 8.1:—

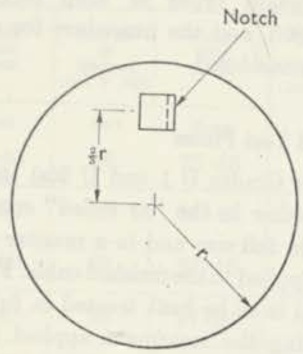


Fig. P 8.1

(d) Additional tests before rejection may be taken in accordance with P 213.

Mechanical Properties

808 In all cases the results of tensile bend and impact tests are to comply with Table P 8.1.

Inspection and Testing of Completed Chain

809 (a) All chain cable and steering chains are to be tested at a proving establishment recognised by the Committee (*see* D 3420). When the (United Kingdom) Anchors & Chain Cables Act* applies the cables are to be tested at a licensed proving house in the United Kingdom.

*The Anchor & Chain Cables Act, 1899, applies to chain cables bought or sold in the United Kingdom for use on a British ship.

The tests detailed in 810 are to be applied.

Each length of chain is to be carefully examined after proof loading and is to be free from significant defects.

810 (a) Proof Loading Test. Each length of chain cable is to be subjected to a proof loading test in an approved testing machine and is to withstand the load given in Table P 8.3A for the appropriate grade and size of cable.

(b) Breaking Test. Breaking test specimens are to be taken as required by Table P 8.2 and are to withstand the load given in Table P 8.3A for the appropriate grade and size of cable. The specimen shall be considered to have passed this test if it has shown no sign of fracture after application of the required load.

Where a breaking test specimen fails, a further specimen is to be cut from the same length of cable and subjected to test. If this retest fails, the length of cable from which it was taken is to be rejected. When this test is also representative of other lengths, each of the remaining lengths is to be individually tested by taking a breaking test specimen from each length of the batch.

For large diameter cables where the required breaking load is greater than the capacity of the testing machines, special consideration will be given to acceptance of an alternative testing procedure.

When the (United Kingdom) Anchors & Chain Cables Act applies one 3-link sample is to be taken from every 27,5 m (15 fathom) (or less) length and the breaking load is to be as given in Table P 8.3B.

(c) Mechanical Tests. For Grade U 3 chain cable, one set of tests (1 tensile and 3 impact test pieces) is to be taken from every four or less 27,5 m (15 fathom) lengths of cable. Test pieces are to be taken clear of the weld and are not to be selected from the same length as that from which the breaking test sample has been taken unless breaking test samples have been taken from every length of the batch.

The results of these tests are to comply with the requirements given in Table P 8.1.

811 Shackles. End and joining shackles are to be subjected to the breaking and proof loads appropriate to the grade of cable for which they are intended. The breaking load shall be applied to at least one shackle out of 25 (1 in 50 for lugless shackles) and this item is to be destroyed and not used as part of an outfit.

Drop forged, cast steel and lugless shackles are to be manufactured to an agreed specification and tensile and impact or bend tests taken. The test samples are to be subjected to the same heat treatment as the shackles.

812 Attachment Links, Adaptor Pieces, Etc., are to be subjected to the breaking and proof loads appropriate to the grade of cable for which they are intended. The breaking load is to be applied to 1 item out of every 25 (or less) and this item is to be destroyed and not used as part of an outfit. Where, however, the items are of increased dimensions, and have been specially approved, the breaking load may be applied to each item and the item so tested included with the outfit.

813 Swivels are to be tested as required by 812 but the breaking load is to be applied to 1 out of every 7 (or less) unless made of increased dimensions.

814 All items subjected to the breaking load are to be destroyed and not used in the outfit except as specifically permitted by 812 and 813 for items of increased dimensions.

TABLE P 8.1

Designation	Method of Manufacture	Tensile Range kg/mm²	Tensile Range ton/in²	Elongation (on 5D) Minimum %	Impact Minimum	Maximum Diameter of Former
Wrought Iron Grade 1(a)	Fire welded	31–41	19·7–26·0	30	—	1T
Mild Steel Grade 1(b)	Fire welded	31–40	19·7–26·0	30	—	1T
U 1(a)	Flash-butt welded	31–41	19·7–26·0	30	—	1T
U 1(b)	,, ,, ,,	41–50	26·0–31·7	25	—	2T
Special Quality Grade U 2(a)	Flash-butt welded or drop forged	50–65	31·7–41·3	22	—	3T
U 2(b)	Cast Steel	50 min.	31·7 min.	22	—	3T
Extra Special Quality Grade U 3(a)	Flash-butt welded or drop forged	70 min.	44·4 min.	17	*6 kg m (43·5 ft lb) at 0°C	—
U 3(b)	Cast Steel	70 min.	44·4 min.	17	*6 kg m (43·5 ft lb) at 0°C	—

Notes: (1) T is equal to the diameter or thickness of the bend test piece.
(2) For Grade U 3 cable, minimum reduction of area *see* 807(c)
(3) Except where otherwise stated Grades 1(a) and 1(b) are to comply with all the requirements for Grade U 1(a) not heat treated.
* Average value from 3 test specimens.

TABLE P 8.2—NUMBER OF BREAKING TESTS

Designation	Method of Manufacture	Number of Breaking Test Specimens
Grade 1(a) 1(b)	Fire welded	One from each length of 27,5 m (15 fathoms) or less
Grade U 1 U 2(a) U 3(a)	Flash-butt welded, or drop forged, and heat treated	One from every four lengths of 27,5 m (15 fathoms) or less
Grade U 1	Flash-butt welded but not heat treated	One from each length of 27,5 m (15 fathoms) or less
Grade U 2(b) U 3(b)	Cast and heat treated	One per heat treatment batch with a minimum of one from every four lengths of 27,5 m (15 fathoms) or less

TABLE P 8.3A—STUD LINK CHAIN CABLE

Chain Diameter	GRADE U 1 Proof Load	GRADE U 1 Breaking Load	GRADE U 2 Proof Load	GRADE U 2 Breaking Load	GRADE U 3 Proof Load	GRADE U 3 Breaking Load	Minimum weight per length of 27,5 m. With Dee Shackle	Minimum weight per length of 27,5 m. With Lugless Shackle
mm	kg	kg	kg	kg	kg	kg	kg	kg
12,5	4700	6720	6720	9400	9400	13 450	107	105
14	5880	8400	8400	11 770	11 770	16 800	130	127
16	7660	10 940	10 940	15 310	15 310	21 950	160	157
17,5	9130	13 040	13 040	18 260	18 260	26 100	190	186
19	10 740	15 340	15 340	21 470	21 470	30 700	220	216
20,5	12 470	17 800	17 800	24 930	24 930	35 600	252	248
22	14 310	20 440	20 440	28 620	28 620	40 900	290	286
24	16 970	24 240	24 240	33 930	33 930	48 500	350	345
26	19 840	28 340	28 340	39 670	39 670	56 700	410	405
28	22 920	32 740	32 740	45 840	45 840	65 500	480	475
30	26 200	37 450	37 450	52 400	52 400	74 900	550	545
32	29 700	42 450	42 450	59 400	59 400	84 850	620	615
34	33 400	47 700	47 700	66 800	66 800	95 450	700	690
36	37 300	53 300	53 300	74 600	74 600	106 600	785	775
38	41 400	59 150	59 150	82 800	82 800	118 300	875	860
40	45 700	65 280	65 280	91 400	91 400	130 550	965	950
42	50 200	71 700	71 700	100 350	100 350	143 400	1055	1040
44	54 850	78 350	78 350	109 700	109 700	156 750	1150	1130
46	59 700	85 300	85 300	119 450	119 450	170 650	1260	1240
48	64 750	92 550	92 550	129 550	129 550	185 050	1370	1345
50	70 000	100 000	100 000	140 000	140 000	200 000	1485	1455
52	75 400	107 750	107 750	150 800	150 800	215 450	1605	1575
54	81 000	115 700	115 700	162 000	162 000	231 400	1725	1690
56	86 750	123 950	123 950	173 500	173 500	247 850	1850	1810
58	92 700	132 400	132 400	185 350	185 350	264 800	1985	1945
60	98 800	141 100	141 100	197 550	197 550	282 250	2125	2075
62	105 050	150 050	150 050	210 100	210 100	300 150	2275	2220
64	111 500	159 250	159 250	222 950	222 950	318 500	2430	2370
66	118 050	168 650	168 650	236 150	236 150	337 350	2590	2525
68	124 800	178 300	178 300	249 600	249 600	356 600	2755	2685
70	131 700	188 150	188 150	263 400	263 400	376 300	2925	2850
73	142 350	203 350	203 350	284 700	284 700	406 700	3185	3100
76	153 300	219 050	219 050	306 650	306 650	438 050	3460	3360
78	160 800	229 750	229 750	321 600	321 600	459 450	3640	3535
81	172 300	246 150	246 150	344 650	344 650	492 350	3940	3820
84	184 150	263 050	263 050	368 250	368 250	526 100	4240	4105
87	196 250	280 350	280 350	392 500	392 500	560 700	4555	4405
90	208 650	298 100	298 100	417 300	417 300	596 150	4870	4705
92	217 100	310 100	310 100	434 150	434 150	620 250	5085	4905
95	229 950	328 500	328 500	459 900	459 900	657 000	5405	5210
97	238 700	341 050	341 050	477 450	477 450	682 050	5630	5425
100	252 000	360 000	360 000	504 000	504 000	720 000	5970	5745
102	261 000	372 900	372 900	522 050	522 050	745 760	6210	5970
105	274 750	392 500	392 500	549 500	549 500	784 980	6580	6320
107	284 050	405 800	405 800	568 100	568 100	811 560	6845	6575
111	302 900	432 700	432 700	605 800	605 800	865 450	7380	7080
114	317 300	453 300	453 300	634 600	634 600	906 600	7795	7475
117	331 950	474 200	474 200	663 850	663 850	948 350	8220	7870
120	346 750	495 350	495 350	693 500	693 500	990 700	8650	8270
122	356 740	509 630	509 630	713 480	713 480	1 019 300	8960	8550
124	366 810	524 010	524 010	733 620	733 620	1 048 030	9275	8835
127	382 060	545 810	545 810	764 130	764 130	1 091 610	9740	9270
130	397 490	567 840	567 840	794 980	794 980	1 135 680	10 210	9710
132	407 860	582 660	582 660	815 720	815 720	1 165 320	10 540	10 005
137	434 090	620 130	620 130	868 180	868 180	1 240 260	11 320	10 750
142	460 710	658 150	658 150	921 410	921 410	1 316 310	12 110	11 500
147	487 670	696 670	696 670	975 340	975 340	1 393 350	12 950	12 300
152	514 940	735 630	735 630	1 029 880	1 029 880	1 471 260	13 890	13 200

or in British units:—

TABLE P 8.3A—STUD LINK CHAIN CABLE

Chain Diameter	GRADE U 1		GRADE U 2		GRADE U 3		Minimum weight per length of 15 fathoms	
	Proof Load	Breaking Load	Proof Load	Breaking Load	Proof Load	Breaking Load	With Dee Shackle	With Lugless Shackle
Inches	Tons	Tons	Tons	Tons	Tons	Tons	Cwt	Cwt
$\frac{1}{2}$	4·77	6·82	6·82	9·55	9·55	13·64	$2\frac{1}{8}$	$2\frac{1}{16}$
$\frac{9}{16}$	6·03	8·61	8·61	12·05	12·05	17·22	$2\frac{5}{8}$	$2\frac{9}{16}$
$\frac{5}{8}$	7·42	10·60	10·60	14·83	14·83	21·19	$3\frac{1}{4}$	$3\frac{3}{16}$
$\frac{11}{16}$	8·95	12·78	12·78	17·90	17·90	25·57	$3\frac{5}{8}$	$3\frac{9}{16}$
$\frac{3}{4}$	10·62	15·17	15·17	21·24	21·24	30·34	$4\frac{3}{8}$	$4\frac{5}{16}$
$\frac{13}{16}$	12·43	17·75	17·75	24·85	24·85	35·50	$5\frac{1}{8}$	$5\frac{1}{16}$
$\frac{7}{8}$	14·36	20·52	20·52	28·73	28·73	41·00	$5\frac{7}{8}$	$5\frac{3}{4}$
$\frac{15}{16}$	16·44	23·49	23·49	32·88	32·88	46·97	$6\frac{3}{4}$	$6\frac{5}{8}$
1	18·65	26·65	26·65	37·30	37·30	53·30	$7\frac{5}{8}$	$7\frac{1}{2}$
$1\frac{1}{8}$	23·50	33·50	33·50	46·90	46·90	67·00	$9\frac{3}{4}$	$9\frac{5}{8}$
$1\frac{3}{16}$	26·05	37·25	37·25	52·10	52·10	74·45	$10\frac{7}{8}$	$10\frac{3}{4}$
$1\frac{1}{4}$	28·80	41·15	41·15	57·60	57·60	82·25	12	$11\frac{7}{8}$
$1\frac{5}{16}$	31·65	45·20	45·20	63·30	63·30	90·40	$13\frac{1}{4}$	$13\frac{1}{16}$
$1\frac{7}{16}$	37·70	53·90	53·90	75·45	75·45	107·80	$15\frac{7}{8}$	$15\frac{11}{16}$
$1\frac{1}{2}$	40·95	58·50	58·50	81·90	81·90	117·00	$17\frac{1}{4}$	17
$1\frac{9}{16}$	44·30	63·30	63·30	88·60	88·60	126·60	$18\frac{3}{4}$	$18\frac{1}{2}$
$1\frac{5}{8}$	47·75	68·25	68·25	95·50	95·50	136·45	20	$19\frac{5}{8}$
$1\frac{3}{4}$	55·05	78·65	78·65	110·10	110·10	157·25	$23\frac{1}{8}$	$22\frac{3}{4}$
$1\frac{13}{16}$	58·85	84·10	84·10	117·70	117·70	168·15	$24\frac{7}{8}$	$24\frac{1}{2}$
$1\frac{7}{8}$	62·80	89·70	89·70	125·60	125·60	179·40	$26\frac{5}{8}$	$26\frac{1}{8}$
2	71·00	101·40	101·40	142·00	142·00	202·85	30	$29\frac{3}{8}$
$2\frac{1}{16}$	75·26	107·51	107·51	150·50	150·50	215·00	$31\frac{7}{8}$	$31\frac{1}{4}$
$2\frac{1}{8}$	79·63	113·75	113·75	159·25	159·25	227·50	$33\frac{3}{4}$	33
$2\frac{3}{16}$	84·10	120·15	120·15	168·25	168·25	240·30	$35\frac{7}{8}$	$35\frac{1}{8}$
$2\frac{5}{16}$	93·40	133·45	133·45	186·80	186·80	266·85	40	$39\frac{1}{8}$
$2\frac{3}{8}$	98·20	140·30	140·30	196·40	196·40	280·55	$42\frac{1}{4}$	$41\frac{1}{4}$
$2\frac{7}{16}$	103·10	147·30	147·30	206·20	206·20	294·55	$44\frac{1}{2}$	$43\frac{3}{8}$
$2\frac{1}{2}$	108·10	154·45	154·45	216·20	216·20	308·85	47	$45\frac{7}{8}$
$2\frac{5}{8}$	118·40	169·15	169·15	236·80	236·80	338·30	52	$50\frac{5}{8}$
$2\frac{11}{16}$	123·70	176·70	176·70	247·40	247·40	353·40	$54\frac{1}{2}$	$53\frac{1}{8}$
$2\frac{3}{4}$	129·10	184·40	184·40	258·20	258·20	368·85	$57\frac{1}{8}$	$55\frac{5}{8}$
$2\frac{7}{8}$	140·15	200·25	200·25	280·35	280·35	400·45	$62\frac{5}{8}$	$60\frac{7}{8}$
3	151·60	216·60	216·60	303·20	303·20	433·15	$68\frac{3}{8}$	$66\frac{3}{8}$
$3\frac{1}{16}$	157·45	224·95	224·95	314·90	314·90	449·85	$71\frac{1}{4}$	$69\frac{1}{8}$
$3\frac{3}{16}$	169·40	242·05	242·05	338·85	338·85	484·05	$77\frac{3}{8}$	75
$3\frac{5}{16}$	181·75	259·60	259·60	363·45	363·45	519·25	$83\frac{5}{8}$	81
$3\frac{7}{16}$	194·35	277·70	277·70	388·75	388·75	555·35	$90\frac{1}{8}$	$87\frac{1}{8}$
$3\frac{9}{16}$	207·35	296·20	296·20	414·65	414·65	592·35	$96\frac{3}{4}$	$93\frac{1}{2}$
$3\frac{5}{8}$	213·95	305·60	305·60	427·85	427·85	611·25	100	$93\frac{1}{2}$
$3\frac{3}{4}$	227·35	324·80	324·80	454·70	454·70	649·55	$106\frac{5}{8}$	$102\frac{3}{4}$
$3\frac{13}{16}$	234·64	335·25	335·25	469·33	469·33	670·50	$110\frac{7}{8}$	$106\frac{3}{4}$
$3\frac{15}{16}$	248·05	354·33	354·33	496·06	496·06	708·65	$116\frac{3}{4}$	$112\frac{1}{2}$
4	255·05	364·35	364·35	510·15	510·15	728·75	$120\frac{5}{8}$	116
$4\frac{1}{8}$	269·35	384·75	384·75	538·65	538·65	769·50	$128\frac{5}{8}$	$123\frac{1}{2}$
$4\frac{3}{16}$	277·89	397·00	397·00	555·77	555·77	793·95	$134\frac{3}{4}$	$129\frac{3}{8}$
$4\frac{3}{8}$	298·65	426·65	426·65	597·30	597·30	853·25	$145\frac{3}{8}$	$139\frac{3}{8}$
$4\frac{1}{2}$	313·70	448·10	448·10	627·35	627·35	896·20	$154\frac{1}{8}$	$147\frac{5}{8}$
$4\frac{5}{8}$	328·90	469·90	469·90	657·85	657·85	939·80	163	156
$4\frac{3}{4}$	344·40	492·00	492·00	688·80	688·80	984·00	172	$164\frac{1}{2}$
$4\frac{13}{16}$	351·25	501·78	501·78	702·49	702·49	1000·36	$176\frac{5}{8}$	$168\frac{5}{8}$
$4\frac{7}{8}$	361·01	515·73	515·73	722·03	722·03	1031·47	$182\frac{1}{8}$	$173\frac{1}{2}$
5	376·02	537·18	537·18	752·06	752·06	1074·36	$191\frac{5}{8}$	$182\frac{1}{2}$
$5\frac{1}{8}$	391·21	558·87	558·87	782·42	782·42	1117·74	$201\frac{3}{8}$	$191\frac{1}{2}$
$5\frac{3}{16}$	401·42	573·45	573·45	802·83	802·83	1146·91	207	$196\frac{1}{2}$
$5\frac{3}{8}$	427·23	610·33	610·33	854·46	854·46	1220·66	$222\frac{3}{8}$	$211\frac{1}{8}$
$5\frac{9}{16}$	453·43	647·75	647·75	906·85	906·85	1295·51	$237\frac{3}{8}$	$225\frac{1}{2}$
$5\frac{3}{4}$	479·96	685·66	685·66	959·93	959·93	1371·34	$253\frac{7}{8}$	241
6	506·80	724·00	724·00	1013·61	1013·61	1448·01	$274\frac{1}{8}$	$260\frac{1}{2}$

TABLE P 8.3B (INCH UNITS)—STUD LINK CHAIN CABLE

(Subject to Anchors and Chain Cables Act.)

Diameter	GRADE				Minimum weight per length of 15 fathoms	
	U 1		U 2			
	Proof Load	Breaking Load	Proof Load	Breaking Load	With Dee Shackle	With Lugless Shackle
Inches	Tons	Tons	Tons	Tons	Cwt	Cwt
7/16	3·40	5·10	4·80	7·10	1 3/4	1 11/16
1/2	4·50	6·75	6·30	9·50	2 1/8	2 1/16
9/16	5·65	8·40	7·90	11·80	2 5/8	2 9/16
5/8	7·00	10·50	9·80	14·70	3 1/4	3 3/16
11/16	8·50	12·75	11·90	17·90	3 5/8	3 9/16
3/4	10·15	15·15	14·20	21·20	4 3/8	4 5/16
13/16	11·90	17·80	16·60	24·90	5 1/8	5 1/16
7/8	13·75	20·65	19·30	28·90	5 7/8	5 3/4
15/16	15·80	23·70	22·10	33·20	6 3/4	6 5/8
1	18·00	27·00	25·20	37·80	7 5/8	7 1/2
1 1/16	20·30	30·40	28·40	42·60	8 5/8	8 1/2
1 1/8	22·75	34·15	31·90	47·80	9 3/4	9 5/8
1 3/16	25·40	38·00	35·50	53·20	10 7/8	10 3/4
1 1/4	28·15	42·15	39·40	59·00	12	11 7/8
1 5/16	31·00	46·50	43·40	65·10	13 1/4	13 1/16
1 3/8	34·00	51·00	47·60	71·40	14 1/2	14 5/16
1 7/16	37·15	55·65	52·00	77·90	15 7/8	15 11/16
1 1/2	40·50	58·70	56·70	82·20	17 1/4	17
1 9/16	43·90	61·40	61·40	86·00	18 3/4	18 1/2
1 5/8	47·50	66·50	66·50	93·10	20	19 5/8
1 11/16	51·25	71·75	71·75	100·50	21 1/2	21 1/8
1 3/4	55·15	77·15	77·15	108·00	23 1/8	22 3/4
1 13/16	59·15	82·75	82·75	115·90	24 7/8	24 1/2
1 7/8	63·25	88·50	88·50	123·90	26 5/8	26 1/8
1 15/16	67·50	94·50	94·50	132·30	28 3/8	27 7/8
2	72·00	100·80	100·80	141·10	30	29 3/8
2 1/16	76·50	107·10	107·10	149·90	31 7/8	31 1/4
2 1/8	81·25	113·75	113·75	159·30	33 3/4	33
2 3/16	86·15	120·50	120·50	168·70	35 7/8	35 1/8
2 1/4	91·15	127·50	127·50	178·50	37 7/8	37
2 5/16	96·25	134·75	134·75	188·75	40	39 1/8
2 3/8	101·50	142·10	142·10	198·90	42 1/4	41 1/4
2 7/16	106·90	149·65	149·65	209·50	44 1/2	43 3/8

(*See Continuation*)

TABLE P 8.3B (INCH UNITS)—STUD LINK CHAIN CABLE *(Continued)*

(Subject to Anchors and Chain Cables Act.)

Diameter	GRADE				Minimum weight per length of 15 fathoms	
	U 1		U 2			
	Proof Load	Breaking Load	Proof Load	Breaking Load	With Dee Shackle	With Lugless Shackle
Inches	Tons	Tons	Tons	Tons	Cwt	Cwt
$2\frac{1}{2}$	112·50	157·50	157·50	220·50	47	$45\frac{7}{8}$
$2\frac{9}{16}$	116·70	163·40	163·40	228·70	$49\frac{1}{2}$	$48\frac{1}{4}$
$2\frac{5}{8}$	120·90	169·25	169·25	237·00	52	$50\frac{5}{8}$
$2\frac{11}{16}$	125·10	175·15	175·15	245·20	$54\frac{1}{2}$	$53\frac{1}{8}$
$2\frac{3}{4}$	129·30	181·00	181·00	253·40	$57\frac{1}{8}$	$55\frac{5}{8}$
$2\frac{13}{16}$	133·40	186·75	186·75	261·50	$59\frac{7}{8}$	$58\frac{1}{4}$
$2\frac{7}{8}$	137·60	192·65	192·65	269·70	$62\frac{5}{8}$	$60\frac{7}{8}$
$2\frac{15}{16}$	141·70	198·40	198·40	277·70	$65\frac{1}{2}$	$63\frac{5}{8}$
3	145·80	204·10	204·10	285·70	$68\frac{3}{8}$	$66\frac{3}{8}$
$3\frac{1}{16}$	149·80	209·70	209·70	293·60	$71\frac{1}{4}$	$69\frac{1}{8}$
$3\frac{1}{8}$	153·75	215·25	215·25	301·40	$74\frac{1}{4}$	72
$3\frac{3}{16}$	157·70	220·75	220·75	309·10	$77\frac{3}{8}$	75
$3\frac{1}{4}$	161·60	226·20	226·20	316·70	$80\frac{3}{8}$	$77\frac{7}{8}$
$3\frac{5}{16}$	165·40	231·50	231·50	324·10	$83\frac{3}{8}$	81
$3\frac{3}{8}$	169·15	236·75	236·75	331·50	$86\frac{7}{8}$	$84\frac{1}{8}$
$3\frac{7}{16}$	172·75	241·80	241·80	338·50	$90\frac{1}{8}$	$87\frac{1}{8}$
$3\frac{1}{2}$	176·40	246·90	246·90	345·70	$93\frac{1}{2}$	$90\frac{3}{8}$
$3\frac{9}{16}$	179·90	251·80	251·80	352·50	$96\frac{3}{4}$	$93\frac{1}{2}$
$3\frac{5}{8}$	183·25	256·50	256·50	359·00	100	$96\frac{1}{2}$
$3\frac{11}{16}$	186·50	261·10	261·10	365·50	$103\frac{3}{8}$	$99\frac{3}{4}$
$3\frac{3}{4}$	189·80	265·70	265·70	372·00	$106\frac{5}{8}$	$102\frac{3}{4}$
$3\frac{13}{16}$	192·90	270·00	270·00	378·00	$109\frac{7}{8}$	$105\frac{7}{8}$
$3\frac{7}{8}$	195·90	274·25	274·25	384·00	$113\frac{1}{4}$	109
$3\frac{15}{16}$	198·80	278·30	278·30	389·65	$116\frac{3}{4}$	$112\frac{1}{4}$
4	201·60	282·20	282·20	395·10	$120\frac{5}{8}$	116
$4\frac{1}{16}$	204·20	285·90	285·90	400·25	$124\frac{5}{8}$	$119\frac{3}{4}$
$4\frac{1}{8}$	206·70	289·40	289·40	405·15	$128\frac{5}{8}$	$123\frac{1}{2}$
$4\frac{3}{16}$	—	—	292·60	409·65	$132\frac{3}{4}$	$127\frac{1}{2}$
$4\frac{1}{4}$	—	—	295·80	414·15	$136\frac{7}{8}$	$131\frac{3}{8}$
$4\frac{5}{16}$	—	—	298·70	418·20	$141\frac{1}{8}$	$135\frac{3}{8}$
$4\frac{3}{8}$	—	—	301·40	422·00	$145\frac{3}{8}$	$139\frac{3}{8}$
$4\frac{7}{16}$	—	—	303·80	425·35	$149\frac{3}{4}$	$143\frac{1}{2}$
$4\frac{1}{2}$	—	—	306·15	428·60	$154\frac{1}{8}$	$147\frac{5}{8}$

TABLE P 8.4—SHORT LINK CHAIN CABLE

Diameter	GRADE				Minimum weight per length of 27,5 m	
	U 1		U 2			
	Proof Load	Breaking Load	Proof Load	Breaking Load	Forged	Electric Welded
mm	kg	kg	kg	kg	kg	kg
11	2250	4500	3150	6300	100	60
12	2700	5400	3800	7600	115	75
13	3200	6400	4500	9000	130	95
14	3650	7300	5200	10 400	145	115
15	4200	8400	5950	11 900	160	135
16	4800	9600	6750	13 500	175	155
17	5450	10 900	7650	15 300	195	175
18	6100	12 200	8600	17 200	215	195
19	6800	13 600	9550	19 100	240	215
20	7550	15 100	10 600	21 200	265	235
21	8300	16 600	11 700	23 400	290	260
22	9100	18 200	12 800	25 600	315	285
23	9950	19 900	14 000	28 000	345	310
24	10 900	21 700	15 300	30 500	375	340
25	11 800	23 600	16 600	33 100	405	370
26	12 800	25 500	17 900	35 800	440	400
27	13 700	27 400	19 300	38 500	475	435
28	14 800	29 500	20 800	41 500	510	470
29	15 900	31 700	22 300	44 500	545	505
30	17 000	34 000	23 900	47 700	580	540
31	18 200	36 300	25 500	50 900	620	575
32	19 400	38 700	27 100	54 200	655	615
33	20 600	41 100	28 900	57 700	695	650
34	21 800	43 600	30 600	61 200	740	690
35	23 100	46 200	32 400	64 800	785	730
36	24 500	48 900	34 300	68 600	830	770
37	25 900	51 700	36 300	72 500	875	810
38	27 300	54 600	38 200	76 400	920	855
39	28 800	57 500	40 300	80 500	970	905
40	30 200	60 400	42 300	84 600	1020	955
41	31 700	63 400	44 500	89 000	1070	1005
42	33 300	66 600	46 700	93 400	1125	1055
43	34 900	69 800	49 000	97 900	1180	1105
44	36 600	73 200	51 300	102 000	1240	1155
45	38 300	76 500	53 600	107 000	1300	1205
46	39 900	79 900	56 000	112 000	1360	1260
47	41 700	83 400	58 200	117 000	1425	1315
48	43 500	87 000	61 000	122 000	1490	1370
49	45 400	90 700	63 500	127 000	1555	1430
50	47 300	94 500	66 200	132 000	1625	1490
51	49 200	98 300	68 800	138 000	1695	1555

or in British units:—

TABLE P 8.4—SHORT LINK CHAIN CABLE

Diameter	GRADE				Minimum weight per length of 15 fathoms	
	U 1		U 2			
	Proof Load	Breaking Load	Proof Load	Breaking Load	Forged	Electric Welded
Inches	Tons	Tons	Tons	Tons	Cwt	Cwt
$\frac{7}{16}$	2·25	4·50	3·20	6·40	2·0	1·5
$\frac{1}{2}$	3·00	6·00	4·20	8·40	2·5	1·9
$\frac{9}{16}$	3·75	7·50	5·30	10·60	3·0	2·4
$\frac{5}{8}$	4·65	9·25	6·55	13·10	3·5	3·0
$\frac{11}{16}$	5·65	11·25	7·95	15·90	4·0	3·6
$\frac{3}{4}$	6·75	13·50	9·45	18·90	4·8	4·3
$\frac{13}{16}$	7·90	15·80	11·10	22·20	5·5	5·0
$\frac{7}{8}$	9·15	18·25	12·85	25·70	6·4	5·8
$\frac{15}{16}$	10·50	21·00	14·75	29·50	7·3	6·7
1	12·00	24·00	16·80	33·60	8·3	7·6
$1\frac{1}{16}$	13·50	27·00	18·95	37·90	9·3	8·6
$1\frac{1}{8}$	15·15	30·25	21·25	42·50	10·4	9·6
$1\frac{3}{16}$	16·90	33·80	23·70	47·40	11·6	10·7
$1\frac{1}{4}$	18·75	37·50	26·25	52·50	12·9	11·8
$1\frac{5}{16}$	20·65	41·25	28·95	57·90	14·1	13·0
$1\frac{3}{8}$	22·65	45·25	31·75	63·50	15·5	14·3
$1\frac{7}{16}$	24·75	49·50	34·70	69·40	17·0	15·6
$1\frac{1}{2}$	27·00	54·00	37·80	75·60	18·4	17·0
$1\frac{9}{16}$	29·25	58·50	41·00	82·00	19·9	18·4
$1\frac{5}{8}$	31·65	63·25	44·35	88·70	21·5	19·9
$1\frac{11}{16}$	34·15	68·25	47·85	95·70	23·1	21·5
$1\frac{3}{4}$	36·75	73·50	51·45	102·90	25·0	23·1
$1\frac{13}{16}$	39·40	78·80	55·20	110·40	26·9	24·8
$1\frac{7}{8}$	42·15	84·25	59·05	118·10	28·9	26·5
$1\frac{15}{16}$	45·00	90·00	63·05	126·10	30·9	28·3
2	48·00	96·00	67·20	134·40	33·0	30·2

STEEL WIRE ROPES FOR STANDING RIGGING, TOWLINES AND MOORING ROPES

Note.—For list of manufacturers of steel wire ropes see Appendix following Chapter Q.

Approval of Works

901 The manufacturer's plant and method of production are to be approved by the Committee. The works are to be at all times open to inspection of the Surveyor and periodical inspections are to be held at intervals not exceeding two years.

Each manufacturer is required to provide on his premises machines suitable for satisfactorily making the prescribed tests. The tensile testing machine is to be of an approved type and is to be calibrated at intervals not exceeding two years. Alternatively, tests carried out by a competent government, municipal or similar responsible body will be accepted.

Material

902 The wire used in the manufacture of the rope is to be drawn from steel made by the open hearth, electric furnace, or other approved process and is to be of homogeneous quality, consistent strength and free from visual defects likely to impair the performance of the rope. The tensile strength of the wire should generally be within the ranges 130–160 kg/mm² (80–100 ton/in²) or 160–180 kg/mm² (100–115 ton/in²).

Galvanising

903 The wire is to be galvanised by the hot dip or the electrolytic process to give a continuous uniform coating complying with the test requirements specified in 909 and 910. The coating may be any of the following grades:—

Grade 1—Heavy coating, drawn after galvanising.

Grade 2—Heavy coating, finally galvanised.

Grade 3—Light coating, drawn after galvanising.

Construction of Ropes

904 The construction of wire ropes for standing rigging, towlines and mooring ropes is generally to be as given in Table P 9.1 but alternative types of wire rope will be specially considered on the basis of an equivalent breaking load and the suitability of the construction for the purpose intended.

TABLE P 9.1

Purpose	Construction of Rope			Construction of Strands
	Strands	Wires	Core	
Standing rigging	6	7	Fibre	6 over 1
	7	7	Wire	6 over 1
	7	19	Wire	12 over 6 over 1
	7	37	Wire	18 over 12 over 6 over 1
Mooring ropes and towlines	6	19	Fibre	12 over 6 over 1
	6	24	Fibre	15 over 9 over fibre core
	6	37	Fibre	18 over 12 over 6 over 1

Note:—See Table D 34.1, Note 3.

Tests

905 A sample of the completed rope shall be subjected to a breaking test to destruction. The sample shall be of sufficient length to provide a clear test length of at least 36 times the rope diameter. Not more than four-fifths of the nominal breaking load may be applied quickly and thereafter the load is to be applied slowly and steadily until the maximum load is obtained.

Tests in which a breakage occurs adjacent to the grips may, at the option of the manufacturer, be neglected.

The actual breaking load is not to be less than that given in an appropriate national standard.

TABLE P 9.2

CONSTRUCTION OF ROPE	PERCENTAGE DEDUCTION
6× 7	10
6×19	13
6×24	13
6×37	17,5
7× 7	15
7×19	18
7×37	22,5

NOTE:—Percentage deductions for other constructions should either be in accordance with a recognised national standard or are to be established by breaking tests carried out on completed ropes.

906 If facilities are not available for making a breaking test on completed ropes intended for standing rigging or mooring ropes, consideration will be given to the acceptance of the determination of the breaking load by the summation of the tests of individual wires and the deduction of a percentage for laying up. This percentage is not to be less than that given in Table P 9.2. Manu-

TABLE P 9.3

Diameter of Coated Wire				Maximum Speed of Testing Turns per Minute
mm		Inch		
From (Including)	Up to (Excluding)	From (Including)	Up to (Excluding)	
	1,5		0·06	90
1,5	3,0	0·06	0·12	60
3,0	5,0	0·12	0·20	30

TABLE P 9.4

Diameter of Coated Wire				Number of Twists			
mm		Inch		Grade 2		Grade 1 or 3	
From (Including)	Up to (Excluding)	From (Including)	Up to (Excluding)	Tested Before Stranding	Tested After Stranding	Tested Before Stranding	Tested After Stranding
	1,3		0·051	15	13	27	24
1,3	2,3	0·051	0·090	15	13	26	23
2,3	3,0	0·090	0·118	14	12	23	20
3,0	4,0	0·118	0·157	12	10	21	18

facturers desiring to adopt this method of testing may be required to arrange for check breaking tests to be carried out on completed ropes.

907 A suitable length shall be cut off the rope, unstranded and straightened, and six wires subjected to a torsion test (*see* 908) and six wires to a wrap test for adhesion of coating (*see* 910).

Alternatively, these tests may be carried out on the wire before the rope is stranded.

Torsion Test

908 The length of sample shall be such as to allow a distance between the grips of 100 times the diameter of wire, but this distance need not exceed 300 mm (12 in). The wire is to be twisted by causing one or both of the vices to be revolved until fracture occurs. The speed of testing should not exceed, for a length equal to 100 times the diameter, that given in Table P 9.3.

(A tensile load not exceeding 2 per cent of the breaking load of the wire may be applied to keep the wire stretched.)

The wire shall withstand, on a length of 100 times the diameter of wire, the number of complete twists given in Table P 9.4.

Weight and Uniformity of Zinc Coating

909 The weight of coating shall comply with the minimum figures shown in the Table P 9.5 when tested in accordance with a recognised standard.

The uniformity of the zinc coating is to be tested by a dip test, carried out in accordance with a recognised standard.

TABLE P 9.5

Diameter of Coated Wire mm		Coating	
		Grade 1 or 2	Grade 3
From (Including)	Up to (Excluding)	gm/m²	gm/m²
0,40	0,50	75	40
0,50	0,60	90	50
0,60	0,80	110	60
0,80	1,00	130	70
1,00	1,20	150	80
1,20	1,50	165	90
1,50	1,90	180	100
1,90	2,50	205	110
2,50	3,20	230	125
3,20	4,00	250	135

or in British units:—

TABLE P 9.5

Diameter of Coated Wire		Coating	
Inch		Grade 1 or 2	Grade 3
From (Including)	Up to (Excluding)	oz/ft^2	oz/ft^2
0·016	0·020	0·25	0·13
0·020	0·024	0·30	0·17
0·024	0·031	0·36	0·20
0·031	0·039	0·43	0·23
0·039	0·047	0·50	0·26
0·047	0·059	0·55	0·30
0·059	0·075	0·60	0·33
0·075	0·098	0·68	0·36
0·098	0·126	0·76	0·41
0·126	0·157	0·82	0·45

Wrap Test for Adhesion of Coating

910 The adhesion of the coating is to be tested by wrapping the wire round a cylindrical mandrel for ten complete turns of wrap. The ratio between the diameter of the mandrel and that of the wire is to be as in Table P 9.6.

TABLE P 9.6

Coating	Wire diameter less than 1,5 mm (0·059 in)	Wire diameter 1,5 mm (0·059 in) and over
Grade 1 or 2	4	6
Grade 3	2	3

After winding on the appropriate mandrel the zinc coating should neither have flaked nor cracked to such an extent that any zinc can be removed by rubbing with the bare fingers.

Certificates

911 Printed forms of certificates, approved by the Committee, are to be signed by the manufacturers and will be supplied to them on application.

Section 10

FIBRE ROPES

General

1001 Fibre ropes intended as mooring ropes may be made of coir, hemp, manilla or sisal or may be composed of synthetic (man-made) fibres. They may be either 3-strand (hawser laid) 4-strand (shroud laid) or 9-strand (cable laid) but other constructions will be specially considered.

1002 Each length of rope is to be manufactured from suitable material of good and consistent quality. Rope materials should, in general, comply with a recognised national standard.

1003 Synthetic fibre ropes are to be suitable for the purpose intended and should comply with a recognised standard.

1004 Weighting and loading matter is not to be added and any added lubricant is to be kept to a minimum. Any rot-proofing or water repellancy treatment shall not be deleterious to the fibre nor shall it add to the weight or reduce the strength of the rope.

Testing

1005 The breaking load is to be determined by testing to destruction a sample cut from the completed rope.

1006 The minimum length of sample to be used in determining the breaking load of a fibre rope is to be as given in Table P 10.1. The specimen is to be loaded to the initial load, given in the table as a percentage of the specified breaking load, and checked for diameter and evenness of lay-up. The load is then to be increased evenly and continuously at the rate shown in the table until the specimen breaks.

If the sample is held by grips and the break occurs within 150 mm (6 in) of the grips the test may be repeated but not more than two tests may be made on any one coil.

TABLE P 10.1—TESTING OF FIBRE ROPES

Material	Test Length mm (in)	Initial Loading	Speed of Loading to Fracture	
			Metres per minute	Inches per minute
Natural Fibre	1800 (72)	2%	0,15 ± 0,05	6 ± 2
Synthetic Fibre	900 (36)	1%	0,10 maximum	4 maximum

1007 Where difficulty is experienced in testing a sample of a completed synthetic fibre rope the Society will consider alternative methods of testing.

Breaking Load

1008 The actual breaking load is not to be less than that given in an appropriate national standard.

Certificates

1009 Printed certificates issued by the manufacturer or a competent government, municipal or similar responsible body will be accepted. The certificate should give the breaking load, test length and speed of testing.

Section 11

APPROVAL OF ELECTRODES AND WIRE-FLUX COMBINATIONS FOR WELDING IN HULL CONSTRUCTION

1101 The manufacturer's plant and method of production of electrodes and fluxes are to be such as to ensure reasonable uniformity in manufacture.

1102 Electrodes and wire-flux combinations will be approved subject to compliance with the following tests. The test pieces are to be prepared in the presence of the Surveyor and all tests carried out under his supervision.

ELECTRODES FOR MANUAL ARC WELDING

1103 Electrodes will be divided into Grades 1, 2 and 3 dependent on the results of the Charpy tests. In addition, if Grade 2 or Grade 3 electrodes comply with the requirements of the hydrogen test as given in 1114, a suffix H will be added to the Grade mark.

Electrodes which have satisfied the requirements of Grade 2 will also be considered as complying with Grade 1 requirements and those which have satisfied the requirements of Grade 3 will be considered as complying with Grades 1 and 2 requirements.

1104 Grade A hull structural steel may be used in the preparation of all test pieces, but at the option of the manufacturer Grades B, C or D steel may be used for Grade 2 electrode test pieces and Grade E steel for Grade 3 electrode test pieces.

1105 The welding current used is to be within the range recommended by the manufacturer and, where an electrode is stated to be suitable for both A.C. and D.C., A.C. is to be used for the preparation of the test assemblies.

Deposited Metal Tests

1106 Tensile and impact tests are to be made, under controlled conditions, on metal deposited from the electrodes.

Two all-weld-metal test assemblies are to be prepared in the downhand position as shown in Fig. P 11.1, one using 4 mm (8 S.W.G.) electrodes and the other using 8 mm ($\frac{5}{16}$ in) diameter electrodes or the largest size manufactured if this is less than 8 mm ($\frac{5}{16}$ in) diameter.

The weld metal is to be deposited in single or multi-run layers according to normal practice, and the direction of deposition of each layer is to alternate from each end of the plate, each run of weld metal being not less than 2 mm (0·08 in) and not more than 4 mm (0·16 in) thick. Between each run the assembly is to be left in still air until it has cooled to 250°C, the temperature being taken in the centre of the weld, on the surface of the seam.

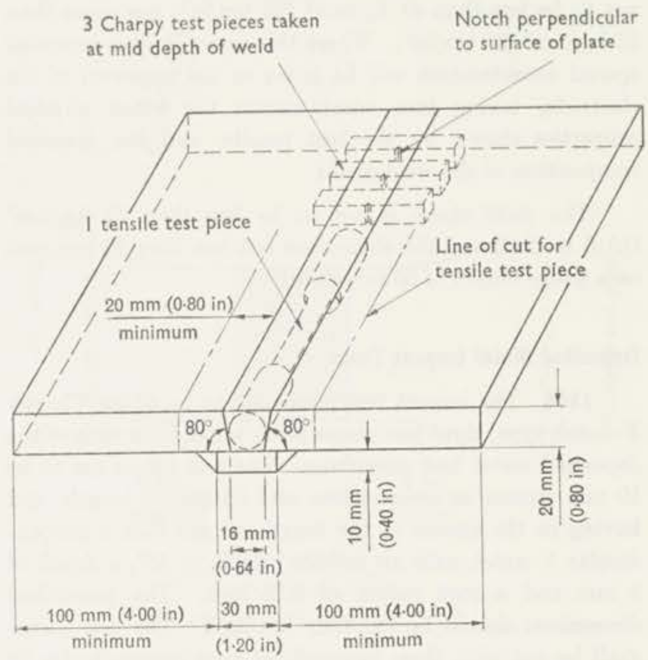


Fig. P 11.1

After being welded the test assemblies are not to be subjected to any heat treatment.

Deposited Metal Tensile Tests

1107 The tensile test pieces, one from each all-weld-metal assembly, are to be machined to the dimensions shown in Fig. P 11.2, care being taken that the longitudinal axis coincides with the centre of the weld, and the mid-thickness of the plates.

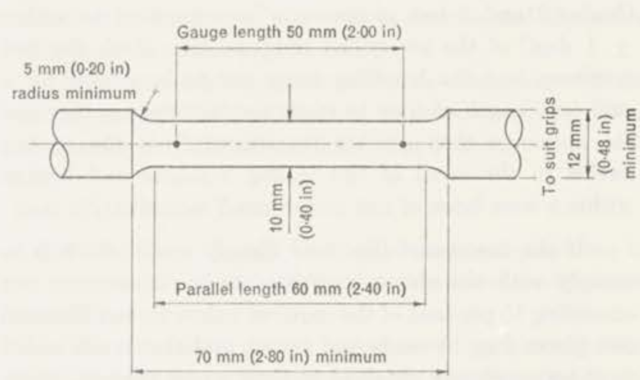


Fig. P 11.2

The tensile test piece may be subjected to a temperature not exceeding 250° C. for a period not exceeding 16 hours for hydrogen removal, prior to testing.

The ultimate tensile strength of each test specimen is not to be less than 41 kg/mm² (26 ton/in²) nor more than 57 kg/mm² (36 ton/in²). Where this upper limit is exceeded special consideration will be given to the approval of the electrode, taking into consideration the other physical properties shown by the test results, and the chemical composition of the weld metal.

The yield stress is not to be less than 31 kg/mm² (19·6 ton/in²) and the elongation not less than 22 per cent on a gauge length of 50 mm (2 in).

Deposited Metal Impact Tests

1108 The impact test pieces are to be of the Charpy V–notch type, three test pieces being taken from each of the deposited metal test assemblies. The test pieces are to be 10 mm square in cross section and 55 mm in length, and having in the centre of the length of one face a perpendicular V–notch with an included angle of 45°, a depth of 2 mm and a root radius of 0,25 mm. The prescribed dimensions should be carefully checked. The test pieces shall be cut with their longitudinal axes perpendicular to the weld and the upper surface 5 mm from the upper surface of the plate.

The notch shall be positioned in the centre of the weld and is to be cut in the face of the test piece perpendicular to the surface of the plate. The tests are to be carried out on an approved Charpy impact machine.

For Grade 1 electrodes the average impact value for the three specimens from each assembly shall not be less than 4,8 kg m (35 ft lb) at about 20°C. The corresponding value for Grade 2 electrodes is 4,8 kg m (35 ft lb) at 0°C and for Grade 3 electrodes 6,2 kg m (45 ft lb) at −10°C or 4,8 kg m (35 ft lb) at −20°C. The test temperature for Grades 2 and 3 test pieces is to be controlled to within ± 1 degC of the prescribed temperature. Both the test specimen and the handling tongs are to be cooled for a sufficient length of time to reach the test temperature and the specimen then quickly transferred from the cooling device to the anvil of the testing machine and broken within a time lapse of not more than 5 seconds.

If the average of the three Charpy specimens fails to comply with the above requirements by an amount not exceeding 15 per cent of the required value, three additional test pieces may be made and tested, and the results added to those previously obtained to form a new average, which must comply with the requirements.

When the average value of the three Charpy specimens is more than 15 per cent below the required value, then six more Charpy test pieces are to be prepared and the average value of these new test pieces is to comply with the requirements.

Butt Weld Tests

1109 Butt weld assemblies as shown in Fig. P 11.3 are to be prepared for each welding position (downhand, vertical and overhead) for which the electrode is recommended by the manufacturer.

The test assemblies are to be made by welding together two plates 15 to 20 mm (0·60 to 0·80 in) in thickness not less than 100 mm (4 in) in width and of sufficient length to allow the cutting out of test specimens of the prescribed number and size. The plate edges are to be prepared to

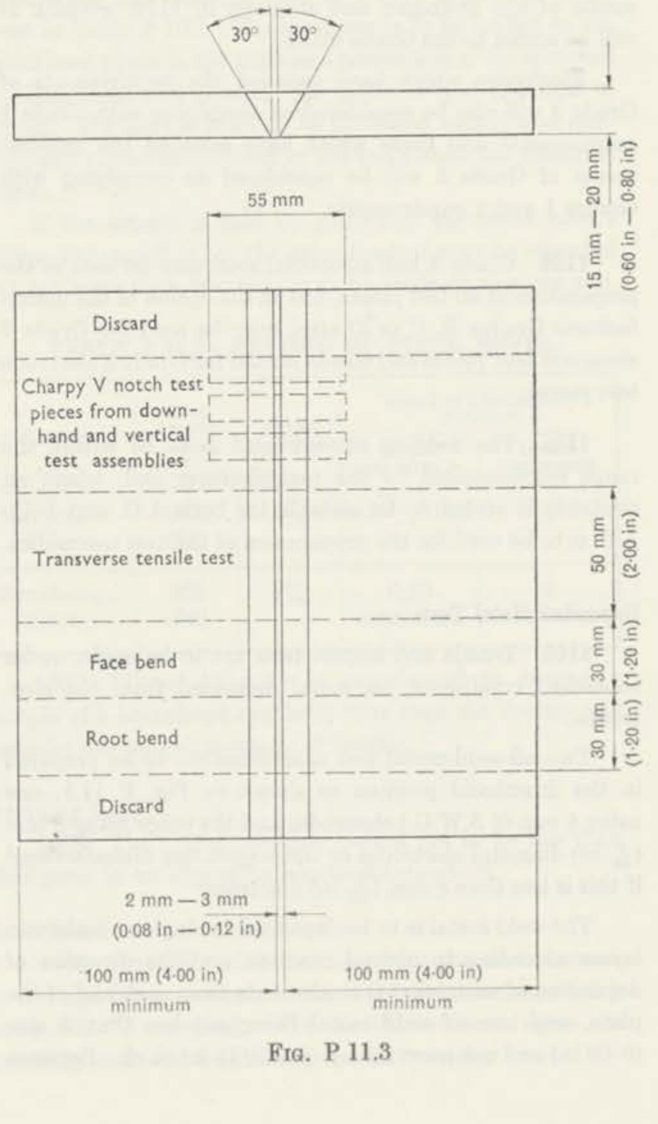


Fig. P 11.3

form a single vee joint, the included angle between the fusion faces being 60° and the root gap being 2 to 3 mm (0·08 to 0·12 in).

Where the electrode is only to be approved in the downhand position an additional test assembly is to be prepared in that position.

The following welding procedure should be adopted in making the test assemblies:—

Downhand (a). First run with 4 mm (8 S.W.G.) electrode. Remaining runs (except last two layers with 5 mm (6 S.W.G.) electrodes or above according to the normal welding practice with the electrodes. The runs of the last two layers with the largest size of electrode manufactured or 8 mm ($\frac{5}{16}$ in) whichever is the less.

Where a second downhand test is required:—

Downhand (b). First run with 4 mm (8 S.W.G.) electrode. Next run with an intermediate size electrode 5 mm (6 S.W.G.) or 6 mm (4 S.W.G.) and the remaining runs with the largest size of electrode manufactured or 8 mm ($\frac{5}{16}$ in) whichever is the less.

Vertical and overhead. First run with 3,15 mm (10 S.W.G.) electrode. Remaining runs with 4 mm (8 S.W.G.) electrodes or possibly with 5 mm (6 S.W.G.) electrodes if this is recommended by the manufacturer for the positions concerned.

In all cases the back sealing runs are to be made with 4 mm (8 S.W.G.) electrodes in the welding position appropriate to each test sample, after cutting out the root run to clean metal. For electrodes suitable for downhand welding only, the test assemblies may be turned over to carry out the back sealing run.

The butts are to be welded using normal welding practice and between each run the assembly is to be left in still air until it has cooled to 250°C the temperature being taken in the centre of the weld, on the surface of the seam.

After being welded the test assemblies are not to be subjected to any heat treatment.

It is recommended that the welded assemblies be subjected to a radiographic examination to ascertain any defects in the weld prior to testing.

Each assembly shall then be cut to form one tensile, one face bend, and one root bend as shown in Fig. P 11.3, together with three Charpy specimens required from the downhand and vertical assemblies.

Butt Weld Tensile Tests

1110 Specimens of the form as shown in Fig. P 11.4 are to be prepared.

The upper and lower surfaces of the weld are to be filed, ground or machined flush with the surface of the plate.

The ultimate tensile strength of each test piece shall not be less than 41 kg/mm² (26 ton/in²).

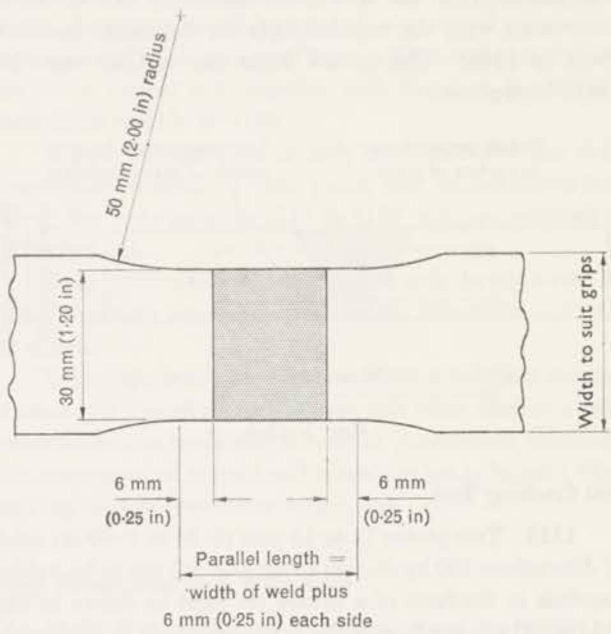


Fig. P 11.4

Butt Weld Bend Tests

1111 The specimens are to be 30 mm (1·20 in) in width. The upper and lower surfaces of the weld are to be filed, ground or machined flush with the surface of the plate and the sharp corners of the specimens rounded to a radius not exceeding 2 mm (0·08 in).

The test specimens are to be capable of withstanding, without fracture, being bent through an angle of 120° over a former having a diameter three times the thickness of the specimen.

One specimen from each welded assembly is to be tested with the face of the weld in tension and the other with the root of the weld in tension.

The test pieces can be considered as complying with the test if, on completion of the test, no crack or defect, at the outer surface of the test specimen, can be seen.

Butt Weld Impact Tests

1112 Three Charpy V–notch impact test pieces are to be machined from each of the downhand and vertical test assemblies.

The test pieces are to be prepared as shown in Fig. P 11.5 of the same dimensions as for the deposited metal impact tests.

The test specimens are to be taken from the middle of the plate thickness with the notch perpendicular to the surface of the plate as shown in Fig. P 11.5.

The average value of the results of the Charpy impact test pieces from the downhand assembly are to be in accordance with the requirements for deposited metal as given in 1108. The results from the vertical assembly are to be reported.

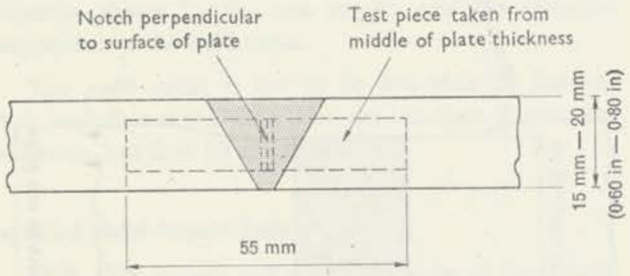


FIG. P 11.5

Hot Cracking Test

1113 Two plates 12 to 15 mm (0·50 to 0·60 in) thick of dimensions 120 by 80 mm (5 by 3·25 in) are to be welded together in the form of a square tee joint as shown in Fig. P 11.6. The lower face of the vertical plate is to be straight and is to fit closely on the plane surface of the lower plate. Any unevenness is to be removed before welding. The tack welds in preparation for the fillet welds are to be positioned at the two ends on a level with the contact surface of the plates. The lower plate is to be stiffened by three transverse stiffeners in order to prevent distortion.

The fillet welding, which is to be made in one pass, is to be carried out in the downhand position and the welding current used is to be the maximum of the range recommended by the manufacturer for the size of electrode used.

The second fillet weld shall be started immediately after the completion of the first fillet weld and at the end of the specimen at which the first fillet weld finished. Both fillet welds are to be executed at a constant speed and without weaving.

For welding the full length of each fillet 120 mm (5 in) the following lengths of electrodes are to be fused:—

Diameter of Electrode	Length of Fused Electrode	
	1st fillet	2nd fillet
4 mm (8 S.W.G.)	200 mm (8 in)	150 mm (6 in)
5 mm (6 S.W.G.)	150 mm (6 in)	100 mm (4 in)
6 mm (4 S.W.G.)	100 mm (4 in)	75 mm (3 in)

After welding, the slag is to be removed from the fillet welds and after complete cooling they are to be examined for cracks by a magnifying glass or by the use of penetrant fluids.

The first fillet weld is then to be cut out by machining or gouging and the second weld broken by closing the two plates together, subjecting the root of the weld to tension. The weld shall then be examined for evidence of hot cracking. There should be no cracking in the fillet welds (except crater cracks) either superficial or internal.

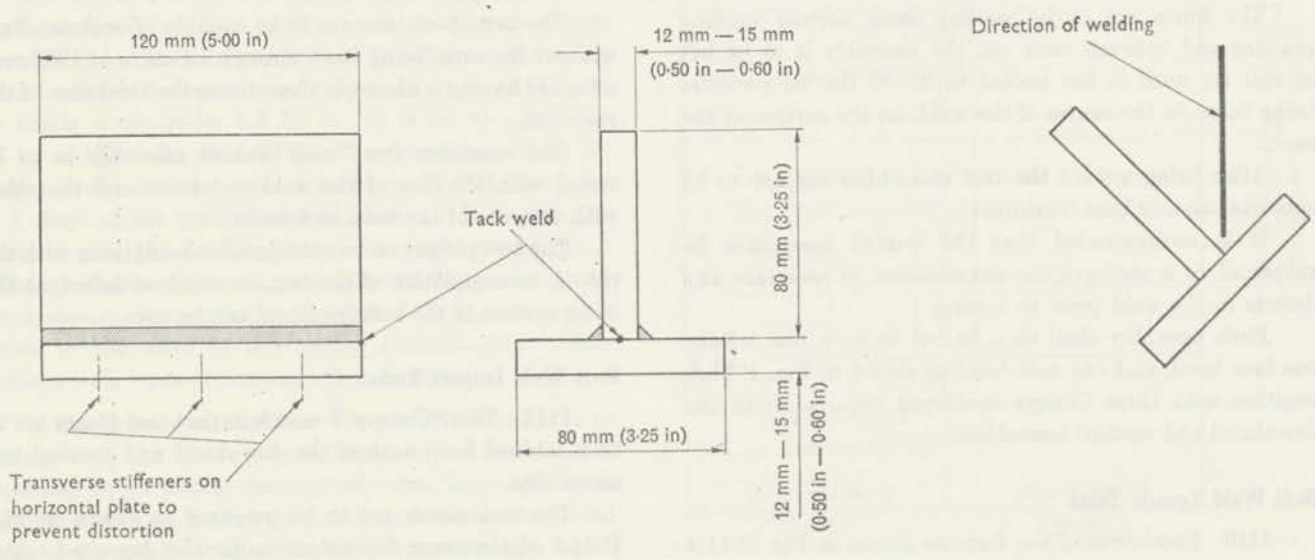


FIG. P 11.6

Hydrogen Test

1114 Electrodes which have satisfied the requirements of Grade 2 or Grade 3 may, at the option of the manufacturer, be submitted to a hydrogen test, and a suffix H will be added to the Grade number to indicate compliance with the test requirements.

Four test specimens are to be prepared measuring 12 by 25 mm (0·5 by 1 in) in cross section by about 125 mm (5 in) in length. The parent metal may be any grade of shipbuilding steel and, before welding, the specimens are to be weighed to the nearest 0,1 gm. On the 25 mm (1 in) surface of each test specimen a single band of welding is to be deposited about 100 mm (4 in) in length by a 4 mm (8 S.W.G.) electrode, using about 150 mm (6 in) of the electrode. The welding is to be carried out with as short an arc as possible and with a current of about 150 amp.

The electrodes, prior to welding, can be submitted to the normal drying process recommended by the manufacturer.

Within thirty seconds of the completion of the welding of each specimen the slag is to be removed and the specimen quenched in water at approximately 20°C. After a further 30 seconds the specimens are to be cleaned and placed in an apparatus suitable for the collection of hydrogen by displacement of glycerine. The glycerine is to be kept at a temperature of 45°C during the test. All four specimens are to be welded and placed in the hydrogen collecting apparatus within 30 minutes.

The specimens are to be kept immersed in the glycerine for a period of 48 hours and, after removal, are to be cleaned in water and spirit, dried and weighed to the nearest 0,1 gm to determine the amount of weld deposited.

The amount of gas evolved is to be measured to the nearest 0,05 c.c. and corrected for temperature and pressure to 20°C and 760 mm Hg.

The amount of hydrogen in terms of cubic centimetres per gram of weld metal is to be reported and is not to exceed an average of 0,1 c.c. per gram for the four specimens tested.

Alternatively, the hydrogen content of the weld metal may be determined by any mercury gas burette type of apparatus, in accordance with a recognised procedure. Proposals for alternative methods of carrying out the test are to be submitted for approval.

Deep Penetration Electrodes

1115 Where, in addition to its use as a normal penetration electrode, a manufacturer desires to demonstrate that an electrode also has deep penetrating properties when used for downhand butt welding and horizontal-vertical fillet welding, the additional tests given in 1116 to 1120 are to be carried out.

Where a manufacturer recommends that an electrode having deep penetrating properties can also be used for downhand butt welding of thicker plates with prepared edges, the electrode will be treated as a normal penetration electrode and the full series of tests in the downhand position are to be carried out, together with the deep penetration tests given in 1116 to 1120.

Where an electrode is only recommended for deep penetration welding of butt joints and horizontal-vertical fillets, the tests given in 1116 to 1120 only are required to be carried out.

Deep penetration electrodes will only be approved as complying with Grade 1 requirements. The suffix D.P. will be added.

Where the manufacturer prescribes a different welding current and procedure for the electrode when used as a deep penetration electrode and a normal penetration electrode, the recommended current and procedure are to be used when making the test specimens in each case.

Deep Penetration Butt Weld Tests

1116 Two plates of thickness equal to twice the diameter of the core of the electrode plus 2 mm (0·08 in) are to be butt welded together with one downhand run of welding from each side. The plates are to be not less than 100 mm (4 in) wide and of sufficient length to allow the cutting out of the test specimens of the correct number and size as shown in Fig. P 11.7.

The joint edges are to be prepared square and smooth and, after tacking, the gap is not to exceed 0,25 mm (0·01 in).

The test assembly is to be welded using an 8 mm ($\frac{5}{16}$ in) diameter electrode or the largest size manufactured if this is less than 8 mm ($\frac{5}{16}$ in).

After welding, the test assembly shall be cut to form two transverse tensile test pieces, two bend test pieces and three Charpy V-notch impact test pieces.

The discards at the end of the welded assemblies are to be not more than 35 mm (1·4 in) wide. The joints of these discards are to be polished and etched and must show complete fusion and interpenetration of the welds. At each cut in the test assembly the joints are also to be examined to ensure that complete fusion has taken place.

Deep Penetration Transverse Butt Weld Tensile Test

1117 Two transverse butt weld tensile test specimens are to be prepared to the dimensions given in Fig. P 11.4.

The upper and lower surfaces of the weld are to be filed, ground or machined flush with the surface of the plate.

The ultimate tensile strength of the test piece shall not be less than 41 kg/mm² (26 ton/in²).

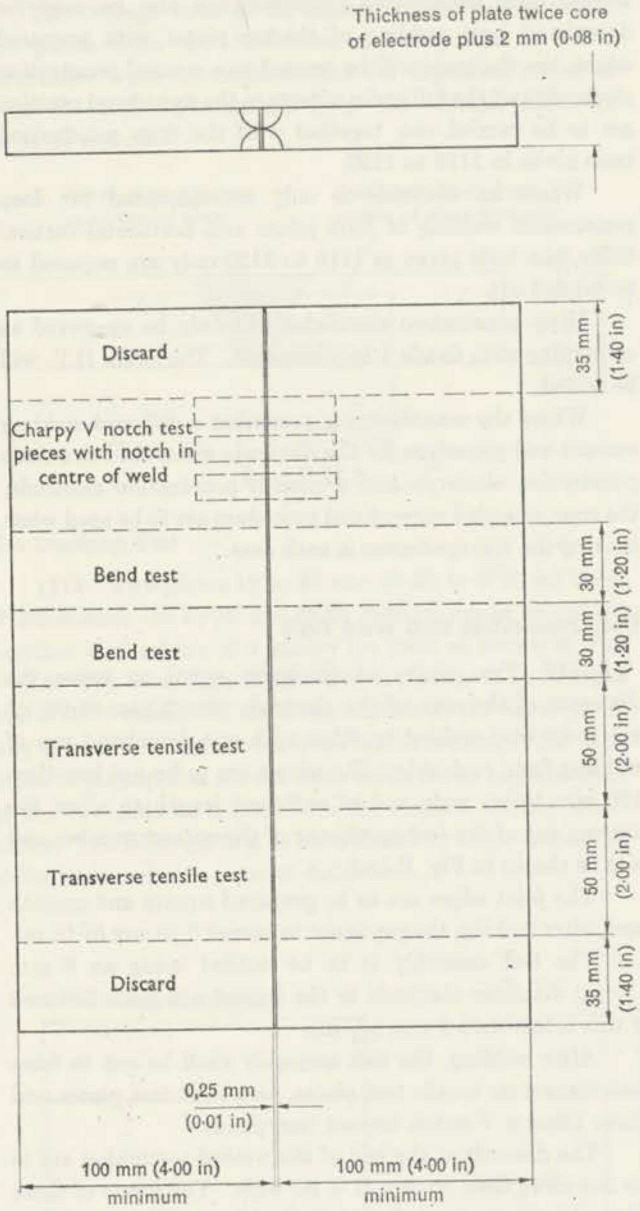


Fig. P 11.7

Deep Penetration Butt Weld Bend Tests

1118 Two butt weld bend tests are to be prepared in accordance with the requirements of 1111 and are to be capable of withstanding, without fracture, being bent through an angle of 120° over a former having a diameter three times the thickness of the specimen.

One test piece shall be tested with the side first welded in tension and one with the other side in tension.

Deep Penetration Butt Weld Impact Tests

1119 Three Charpy V-notch impact test pieces are to be prepared, the notch being in the centre of the weld.

The dimensions of the test pieces are to be as given in 1108. The longitudinal axes of the test pieces are to be perpendicular to the direction of the weld, and they are to be taken from the centre of the plate thickness. The notch is to be cut in the face of the test piece perpendicular to the surface of the plate.

The average impact values for the three specimens taken from the centre of the weld shall not be less than 4,8 kg m (35 ft lb) at about 20°C.

Deep Penetration Fillet Weld Test

1120 A fillet weld assembly is to be prepared as shown in Fig. P 11.8 with plates about 12,5 mm (0·5 in) in thickness.

The welding shall be carried out with one run for each fillet with plate A in the horizontal plane during the welding operations. The length of the fillet is to be 160 mm (6·5 in) and the gap between the plates is to be not more than 0,25 mm (0·01 in).

The fillet weld on one side of the assembly shall be carried out with a 4 mm (8 S.W.G.) electrode and that on the other side with the maximum size of electrode manufactured. The welding current used is to be within the range recommended by the manufacturer and the welding is to be carried out using normal welding practice.

The welded assembly shall be cut by sawing or machining within 35 mm (1·4 in) of the ends of the fillet welds and the joints are to be polished and etched. The welding

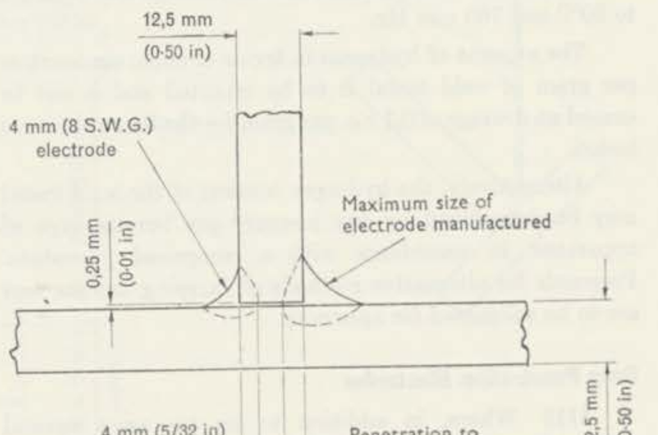


Fig. P 11.8

of the fillet made with a 4 mm (8 S.W.G.) electrode is to show a penetration of 4 mm ($\frac{5}{32}$ in) (*see* Fig. P 11.8) and the corresponding penetration of the fillet made with the maximum size of electrode manufactured is to be reported.

Chemical Analysis

1121 The chemical analysis of the weld metal made by the electrode is to be supplied by the manufacturer.

1122 The Committee is to be notified of any alteration proposed to be made in the process of manufacture subsequent to approval.

Maker's Certificate

1123 Each carton or package of approved electrodes is to contain a certificate from the manufacturer on the following lines:—

> "The .... company certifies that the composition and quality of these electrodes conform with those of the electrodes used in making the test pieces submitted to and approved by the Committee of Lloyd's Register of Shipping".

Periodical Inspection of Maker's Works and Annual Tests

1124 All establishments where approved electrodes are manufactured shall be subject to annual inspection. On these occasions, samples of the approved electrodes shall be subjected to at least the following tests:—

One tensile and three impact specimens in duplicate are to be made from deposited metal as set forth in 1106, 1107 and 1108. One group of specimens is to be prepared using one size of electrode and one using another, neither size being smaller than 4 mm (8 S.W.G.) nor larger than 8 mm ($\frac{5}{16}$ in).

The ultimate tensile stress, yield stress and elongation are to be in accordance with 1107 and the impact properties in accordance with 1108 for the approved Grade.

For electrodes approved for downhand deep penetration butts and horizontal vertical fillet welds the following tests are to be carried out:—

Two plates of thickness twice the core of the electrode plus 2 mm (0·08 in) are to be butt welded together with one downhand run of welding from each side using a 6 mm (4 S.W.G.) electrode, or the largest size made if less than 6 mm (4 S.W.G.). The plates are to be not less than 100 mm (4 in) wide and of sufficient length to cut out one transverse tensile specimen, two bend test specimens and three Charpy V-notch impact specimens to the dimensions shown in Fig. P 11.7. The notch in the Charpy specimens is to be taken in the centre of the weld metal.

The dimensions of the test pieces and the requirements to be fulfilled are as set forth in the original approval tests in 1117, 1118 and 1119.

At each cut in the test assembly, the joints are to be examined to ensure that complete fusion has taken place.

For those electrodes which are approved for normal penetration welding and for deep penetration properties in the downhand position, these tests are to be carried out in addition to the deposited metal tests for normal penetration electrodes.

Additional Tests

1125 If any of the above tests fail, test pieces in duplicate of the same type are to be prepared (if possible using electrodes from the same batch) and are to be satisfactorily tested. (For special requirements for Charpy tests see 1108.)

1126 The Committee may require, in any particular case, such additional tests or requirements as may be necessary.

WIRE-FLUX COMBINATIONS FOR SUBMERGED ARC WELDING

1127 The tests are intended for automatic or semi-automatic single electrode submerged arc welding of hull structural steel. The wire-flux combinations are divided into two categories:—

(a) For use with the multi-run technique.

(b) For use with the two-run technique; in this case a butt weld is made with one run from each side.

Where a manufacturer states that a particular wire-flux combination is suitable for welding with both techniques, both series of tests are to be carried out.

1128 Wire-flux combinations will be divided into Grades 1, 2 and 3, dependent on the results of the Charpy tests. Those which have satisfied the requirements of Grade 2 will also be considered as satisfying Grade 1 requirements and those which have satisfied the requirements of Grade 3 will be considered as complying with Grades 1 and 2 requirements.

The suffix T, M or TM will be added to the grade mark to indicate two-run technique, multi-run technique, or both techniques respectively.

The welding current may be either A.C. or D.C. (electrode positive or negative) according to the recommendation of the manufacturer. If both A.C. and D.C. are recommended, A.C. is to be used for the tests.

Multi-run Technique

1129 When approval for use with multi-run technique is required deposited metal and butt weld tests are to be carried out.

Deposited Metal Tests

1130 Tensile and impact tests are to be made, under controlled conditions, on metal deposited from the wire-flux combination.

An all-weld-metal test assembly is to be prepared in the downhand position as shown in Figs. P 11.9 and P 11.10, using any grade of hull structural steel.

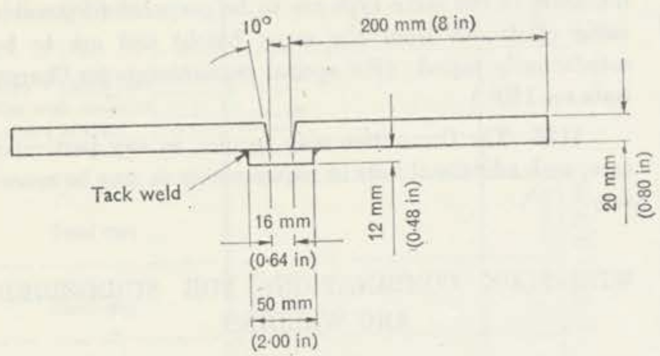


Fig. P 11.9

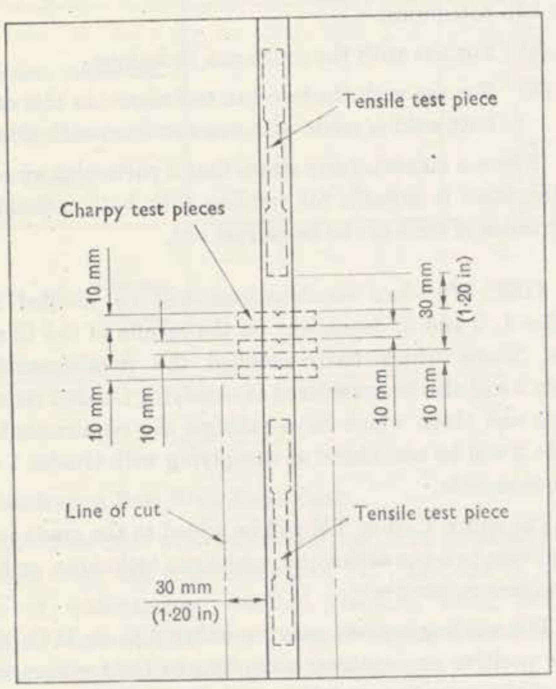


Fig. P 11.10

The bevelling of the plate edges is to be carried out by machining or mechanised gas cutting. In the latter case, any remaining scale is to be removed from the bevelled edges.

The direction of deposition of each run is to alternate from each end of the plate and after completion of each run the flux and welding slag is to be removed. Between each run the assembly is to be left in still air until it has cooled to 250°C, the temperature being taken in the centre of the weld, on the surface of the seam. The thickness of the layer is to be not less than the diameter of the wire but not less than 4 mm (0·16 in).

The welding conditions (amperage, voltage and rate of travel) are to be in accordance with the recommendations of the manufacturer and are to conform with normal, good welding practice for multi-run welding.

The welded assembly is to be cut longitudinally at a distance of 30 mm (1·20 in) from the edges of the weld and then cut transversely.

Deposited Metal Tensile Tests

1131 Two tensile test pieces are to be machined to the dimensions shown in Fig. P 11.2, care being taken that the longitudinal axis coincides with the centre of the weld, and the mid-thickness of the plates.

The tensile test pieces may be subjected to a temperature not exceeding 250°C for a period not exceeding 16 hours for hydrogen removal, prior to testing.

The ultimate tensile strength of each test specimen is to be not less than 41 kg/mm^2 (26 ton/in^2) nor more than 57 kg/mm^2 (36 ton/in^2). Where this upper limit is exceeded special consideration will be given to the approval of the wire-flux combination, taking into consideration the other physical properties shown by the test results, and the chemical composition of the weld metal.

The yield stress is to be not less than 31 kg/mm^2 (19·6 ton/in^2) and the elongation not less than 22 per cent on a gauge length of 50 mm (2 in).

Deposited Metal Impact Tests

1132 The impact test pieces are to be of the Charpy V-notch type, three test pieces being taken from the deposited metal test assembly.

The dimensions of the test pieces are to be as given in 1108.

The test pieces are to be cut with their longitudinal axes perpendicular to the weld and the upper surface

5 mm (0·20 in) from the upper surface of the plate. The notch is to be positioned in the centre of the weld and is to be cut in the face of the test pieces perpendicular to the surface of the plate as shown in Fig. P 11.10. The tests are to be carried out on an approved Charpy impact machine.

For Grade 1 combinations the average impact value of the specimens shall be not less than 3,5 kg m (25 ft lb) at about 20°C. The corresponding value for Grade 2 combinations is 3,5 kg m (25 ft lb) at 0°C and for Grade 3 combinations 4,5 kg m (33 ft lb) at −10°C, or 3,5 kg m (25 ft lb) at −20°C. The test temperature for Grades 2 and 3 test pieces is to be controlled to within ± 1 degC of the prescribed temperature and the test procedure laid down in 1108 is to be followed.

Butt Weld Tests

1133 A butt weld assembly as shown in Fig. P 11.11 is to be prepared in the downhand position by welding together two 20 mm (0·80 in) plates not less than 150 mm (6 in) in width and of sufficient length to allow the cutting out of test specimens of the prescribed number and size.

For Grades 1 and 2 wire-flux combinations Grade A steel is to be used and for Grade 3 wire-flux combinations any grade of steel may be used.

The plate edges are to be prepared to form a single vee joint, the included angle between the fusion faces being 60° and the root face being 4 mm (0·16 in). The bevelling of the plate edges is to be carried out by machining or mechanised gas cutting. In the latter case, any remaining scale is to be removed from the bevelled edges.

The welding is to be carried out by the multi-run technique and the welding conditions are to be the same as those adopted for the deposited metal test assembly.

The back sealing run is to be applied in the downhand position after cutting out the root run to clean metal.

After being welded the test assembly is not to be subjected to any heat treatment.

It is recommended that the welded assembly be subjected to a radiographic examination to ascertain any defects in the weld prior to testing.

The assembly shall then be cut to form two tensile, two face bend, two root bend and three impact test pieces as shown in Fig. P 11.11.

Butt Weld Tensile Tests

1134 The two transverse tensile test pieces are to be machined to the dimensions shown in Fig. P 11.4.

The upper and lower surfaces of the weld are to be filed, ground or machined flush with the surface of the plate.

The ultimate tensile strength of each test piece is to be not less than 41 kg/mm² (26 ton/in²).

Butt Weld Bend Tests

1135 Four transverse bend test specimens, 30 mm (1·20 in) in width, are to be taken from the welded assembly.

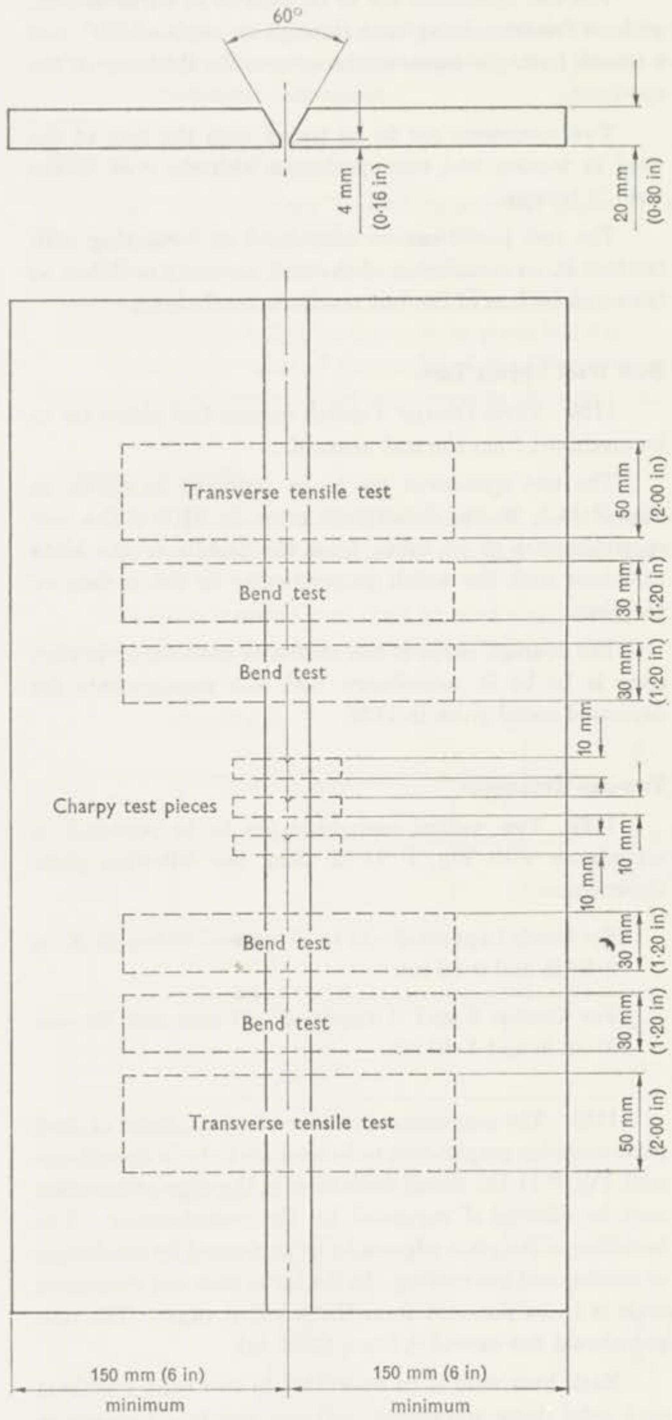


Fig. P 11.11

The upper and lower surfaces of the weld are to be filed, ground or machined flush with the surface of the plate and the sharp corners of the specimens rounded to a radius not exceeding 2 mm (0·08 in).

The test specimens are to be capable of withstanding, without fracture, being bent through an angle of 120° over a former having a diameter three times the thickness of the specimen.

Two specimens are to be tested with the face of the weld in tension and two specimens with the root of the weld in tension.

The test pieces can be considered as complying with the test if, on completion of the test, no crack or defect at the outer surface of the test specimen can be seen.

Butt Weld Impact Tests

1136 Three Charpy V-notch impact test pieces are to be machined from the test assembly.

The test specimens are to be prepared as shown in Fig. P 11.5, to the dimensions given in 1108. The test specimens are to be taken from the middle of the plate thickness with the notch perpendicular to the surface of the plate.

The average value of the results of the Charpy impact tests is to be in accordance with the requirements for deposited metal given in 1132.

Two-run Technique

1137 Two welded assemblies are to be prepared in accordance with Fig. P 11.12 using the following plate thickness:—

For Grade 1 approval—12 to 15 mm and 20 mm (0·50 to 0·60 in and 0·80 in).

For Grades 2 and 3 approval—20 mm and 35 mm (0·80 in and 1·40 in).

1138 The maximum diameter of wire, grades of steel plate and edge preparation to be used are to be in accordance with Fig. P 11.13. Small deviations in the edge preparation may be allowed if requested by the manufacturer. The bevelling of the plate edges is to be performed by machining or mechanised gas cutting. In the latter case any remaining scale is to be removed from the bevelled edges. The root gap should not exceed 0,7 mm (0·03 in).

Each butt weld is to be welded in two runs, one from each side, using amperages, voltages and travel speeds in accordance with the recommendations of the manufacturer and normal good welding practice.

After completion of the first run, the flux and welding slag are to be removed and the assembly is to be left in still air until it has cooled to 100°C., the temperature being taken in the centre of the weld, on the surface of the seam.

After being welded the test assemblies are not to be subjected to any heat treatment.

It is recommended that the welded assemblies be subjected to radiographic examination to ascertain any defects in the weld prior to testing.

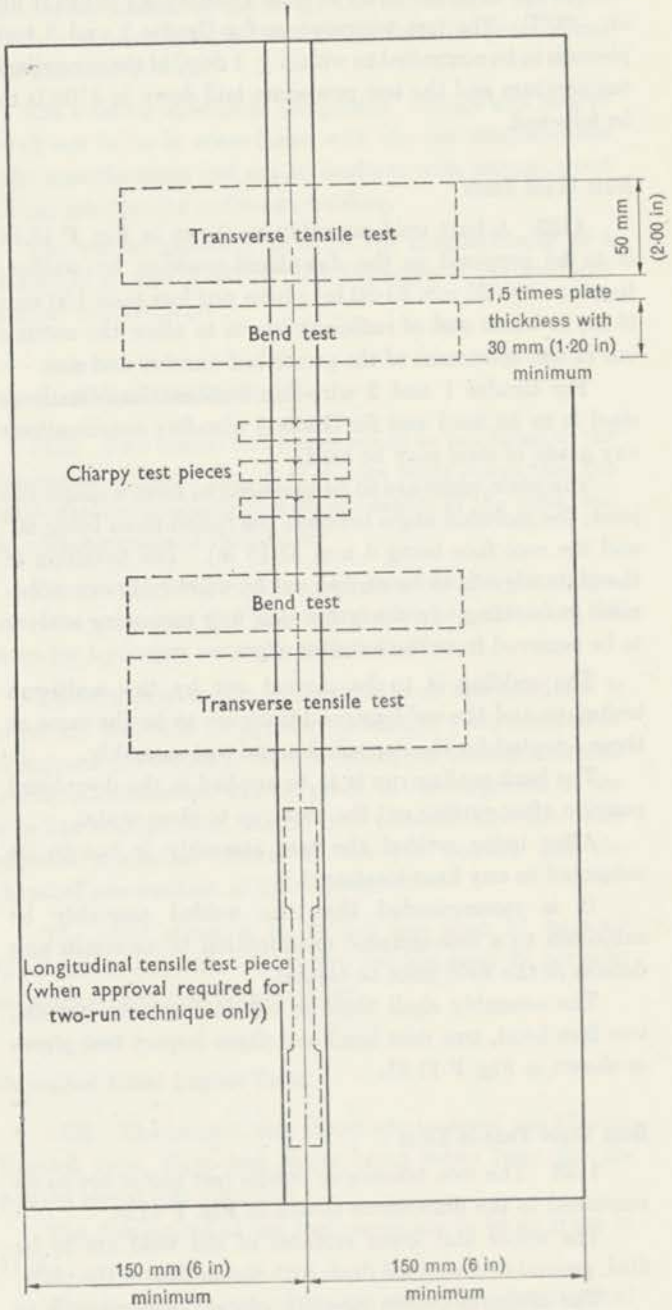


Fig. P 11.12

The assemblies shall each be cut transversely to form two tensile test pieces, two bend test pieces and three impact test pieces as shown in Fig. P 11.12. The edges of two of the discards are to be polished and etched, and must show complete fusion and interpenetration of the welds. At each cut in the test assembly, the edges are also to be examined to ensure that complete fusion has taken place.

Where the combination is to be used for two-run technique only, a longitudinal tensile test is also to be made in accordance with Fig. P 11.12 on the thicker plate tested.

Butt Weld Tensile Tests

1139 The two tensile test pieces cut transversely from each welded assembly are to be prepared as set forth in 1134 for multi-run technique.

The ultimate tensile strength of each test piece is to be not less than 41 kg/mm² (26 ton/in²).

The longitudinal tensile piece is to be machined to the dimensions shown in Fig. P 11.2, and the longitudinal axis is to coincide with the centre of the weld about 7 mm (0·28 in) below the plate surface on the side from which the second run is made. The test piece may be heat treated as set out in 1131. The results of the test are to be the same as those specified in 1131 for the deposited metal tensile tests for multi-run technique test pieces.

Butt Weld Bend Tests

1140 Two transverse bend tests are to be taken from each welded assembly. The width of the test piece is to be 1,5 times the thickness of the plate with a minimum of 30 mm (1·20 in) for plates up to 20 mm (0·80 in) thick, and the test pieces are to be prepared in accordance with 1135.

One specimen from each assembly is to be tested with the side first welded in tension and one with the other side in tension.

The results of the tests and the conditions for acceptance are to be the same as those specified in 1135 for the multi-run technique test pieces.

Butt Weld Impact Tests

1141 Three Charpy V-notch impact test pieces are to be machined from each welded assembly.

The position of the test piece and of the notch in relation to the welded seam is shown in Fig. P 11.14, and the dimensions of the test piece are to be as given in 1108.

The average value of the results of the Charpy tests is to be in accordance with the requirements given in 1132.

Chemical Analysis

1142 The chemical analysis of the weld metal made by the wire-flux combination is to be supplied by the manufacturer.

The plate material used shall have an analysis which is representative of the grade of steel laid down for the test.

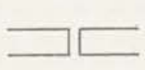
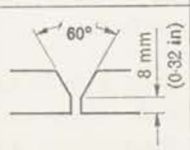
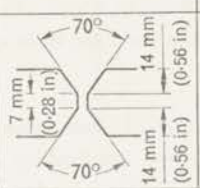
Plate thickness	Preparation	Maximum diameter of wire	Grade of wire/flux combination	Grade of steel
12 mm — 15 mm (0·50 in — 0·60 in)		5 mm (0·20 in)	1	A
20 mm (0·80 in)		6 mm (0·24 in)	1	A
			2	A
			3	C, D or E
35 mm (1·40 in)		7 mm (0·28 in)	2	B, C or D
			3	C, D or E

FIG. P 11.13

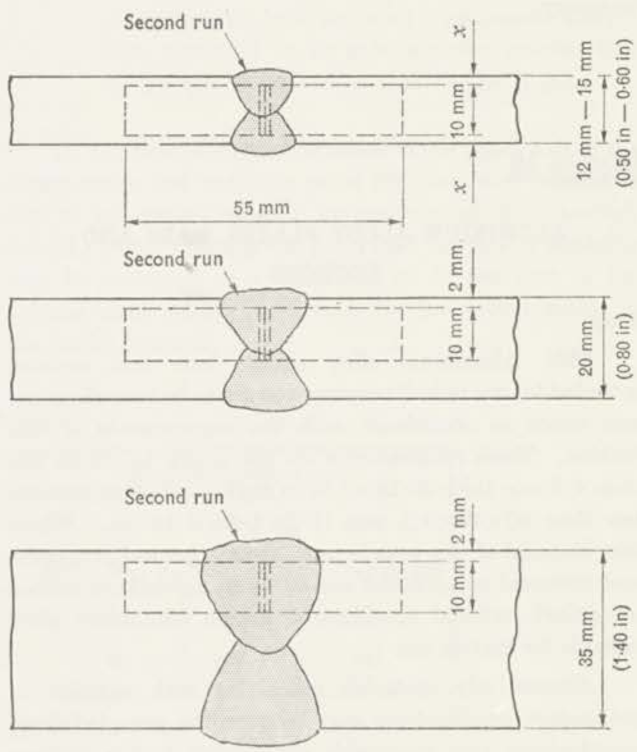


FIG. P 11.14

Periodical Inspection of Maker's Works and Annual Tests

1143 All establishments where approved electrodes are manufactured shall be subject to annual inspection. On these occasions, samples of the approved wire-flux combinations shall be subject to at least the following tests:—

MULTI-RUN TECHNIQUE:—
Deposited metal tests—two tensile and three impact tests.

TWO-RUN TECHNIQUE:—
Transverse specimens taken from a 20 mm. butt weld assembly—two tensile, two bend and three impact tests.

The specimens are to be prepared and tested in accordance with, and on grades of steel laid down for, first approval.

Additional Tests

1144 If any of the above tests fail, test pieces in duplicate of the same type are to be prepared (if possible using wire-flux combination from the same batches) and are to be satisfactorily tested. For special requirements for additional Charpy tests *see* 1108.

1145 The Committee may require, in any particular case, such additional tests or requirements as may be necessary.

Section 12

ALUMINIUM ALLOY PLATES, BARS AND SECTIONS

Scope

1201 Aluminium alloy plates, bars and sections intended for use in hull construction are to be manufactured and tested in accordance with the requirements of this Section. These requirements do not apply to plates less than 4,5 mm thick (0·18 in) or to angles and other sections less than 40×40×4,5 mm (1·5×1·5×0·18 in). Where thin material of this type is used, the mechanical properties and chemical composition are to be in accordance with a recognised national specification for an aluminium alloy suitable for marine use.

Alternatively, materials complying with national or proprietary specifications may be accepted provided these specifications give reasonable equivalence to the requirements of this Section.

Manufacture

1202 Aluminium alloys are to be manufactured at works approved by the Committee and a list of approved manufacturers is given in the appendices at the end of Chapter Q.

The alloys may be cast in either ingot moulds or by an accepted continuous casting process.

Plates are to be formed by rolling and may be hot or cold finished. Bars and sections may be formed by extrusion, rolling or by drawing.

Chemical Composition

1203 (*a*) Samples for chemical analysis are to be taken representative of each cast or by an equivalent procedure where a continuous melting process is employed.

The chemical composition of these samples is to comply with the requirements of Table P 12.1.

(*b*) Where it is proposed to use alloys not specified in Table P 12.1 details of chemical composition, heat treatment and mechanical properties are to be submitted for approval.

Heat Treatment

1204 Grade AL 1 alloys may be supplied in either the "as manufactured" or "annealed" conditions provided that the mechanical properties comply with the values given in Table P 12.3. Grade AL 2 alloys are to be supplied in the solution treated and precipitation hardened condition.

Test Material

1205 (*a*) Material of the same section and thickness produced in the same way and of the same chemical composition, is to be presented for testing in batches of not more than 4000 kg (4 tons).

If the material is supplied in the heat treated condition, then each batch is to be subjected to the same finishing treatment in a continuous furnace or heat treated in the same furnace charge in a batch type furnace.

(*b*) At least one tensile test piece is to be taken from material representative of each batch. These are to be cut with their length transverse to the principal direction of rolling for plates over 300 mm (12 in) in width. For narrow plates and for sections and bars the tests are to be cut in the longitudinal direction.

(*c*) Material for the preparation of these tests is not to be cut until heat treatment (where applicable) has been completed nor until it has been identified by the Surveyor or an authorised deputy.

TABLE P 12.1

Grade	AL 1	AL 2
Copper	0,10% max.	0,10% max.
Magnesium	3,5–5,6%	0,4–1,4%
Silicon	0,5% max.	0,6–1,6%
Iron	0,5% max.	0,5% max.
Manganese	1,0% max.	0,2–1,0%
Zinc	0,2% max.	0,2% max.
Chromium	0,35% max.	0,35% max.
Titanium and other grain refining elements	0,2% max.	0,2% max.
Aluminium	The remainder	The remainder

(*d*) Any straightening of test pieces which may be required is to be done cold and the test pieces shall not receive further heat treatment or mechanical working before being tested except by machining to shape.

(*e*) For routine purposes, tensile test pieces from plates and sections are to be of square or rectangular cross section. These are to be machined to a minimum width of 12,0 mm (0·47 in) and are to be of the full thickness of the material with the wrought surfaces retained. Machined test pieces of circular cross section may, however, be used as an alternative provided the diameter is not less than 10 mm (0·399 in). The dimensions are to be as shown in Table P 12.2. The ends may be machined in a form suitable for the grips of the testing machine provided there is an adequate radius between the test length and the enlarged ends.

Round bars may be tested in full section or test pieces may be machined in accordance with the dimensions given in Table P 12.2.

Mechanical Properties

1206 (*a*) All tests are to be carried out in the presence of the Surveyor or an authorised deputy. The 0,2 per cent proof stress, tensile strength and percentage elongation are to be determined.

(*b*) The 0,2 per cent proof stress is to be determined either by:—

(i) drawing a line parallel to the straight elastic portion of an accurate load/extension diagram and distant from it by an amount representing 0,2 per cent of the extensometer gauge length. The point or intersection of this line with the plastic portion of the diagram represents the proof load, from which the 0,2 per cent proof stress can be calculated;

or (ii) subjecting the test piece to the specified minimum proof stress and removing the load when the test piece shall not have acquired a permanent elongation, measured by an extensometer, greater than 0,2 per cent of the extensometer gauge length.

(*c*) The rate of increase of stress in the upper half of the elastic range and until the proof load has been reached is not to be greater than 1 kg/mm²/second (0·6 ton/in²/second.) After reaching the proof load the rate of straining may be increased to a maximum of 40 per cent of the original gauge length per minute for the determination of the tensile strength.

TABLE P 12.2

Cross Section	Gauge Length	Minimum Parallel Length	
Square or Rectangular	$5{,}65\sqrt{S_o}$ or 50 mm (2 in)	$7{,}15\sqrt{S_o}$	
		$50+1{,}5\sqrt{S_o}$ mm	$(2+1{,}5\sqrt{S_o}$ in)
Circular	5d or 50 mm (2 in)	5,5d	
		$50+\frac{d}{2}$ mm	$(2+\frac{d}{2}$ in)

S_o = Cross sectional area of test piece,

d = diameter of test piece.

(*d*) The results of all tensile tests are to comply with the values given in Table P 12.3.

(*e*) Where the tensile test piece representative of a batch fails to meet the test requirements and the Surveyor considers the results obtained from the fractured test piece do not fairly represent the quality of the batch, two further tensile test pieces are to be taken. These additional tests are to be prepared from material adjacent to the original test. In such cases the quality of the batch is to be judged by the result of the re-tests and not by the original test which failed.

When a test covering a batch of material fails and one or both of the re-tests also fail then the item or piece from which the tests were prepared is to be rejected. At the discretion of the Surveyor further tensile test pieces may be selected from at least two pieces of the remaining material in the batch for testing in accordance with the specified requirements.

Where material is tested in the heat treated condition and fails test, the whole of the material represented by the test piece may be re-heat treated and re-submitted for test provided that the material is not solution heat treated more than three times, i.e., original and two re-treatments.

Inspection

1207 (*a*) The manufacturer shall afford the Surveyors all necessary facilities and access to all relevant parts of the works to enable them to verify that the approved method of manufacture is adhered to, for the selection of the test material, the witnessing of tests and the examination of material as required by the Rules.

(*b*) Surface inspection and verification of dimensions are the responsibility of the manufacturer, and acceptance by the Surveyors of material later found to be defective shall not absolve the manufacturer from this responsibility.

(*c*) Materials are to be free from defects of such a nature as would be harmful in service. The surface finish is to be in accordance with good practice and surfaces are not to be treated in any way that may invalidate the surface examination.

Where there is visible evidence to doubt the soundness of any material, such as flaws in test pieces or suspicious surface marks, the Surveyor may require the manufacturer to prove the material by a suitable method.

(*d*) In the event of any material proving unsatisfactory during subsequent working, machining or fabricating, due to faults in manufacture, such material is to be rejected notwithstanding any previous certification and such tests of further material from the same cast may be made as the Surveyor may consider desirable.

Repair of defective material

1208 Slight surface imperfections may be removed by mechanical means, provided the prior agreement of the Surveyor is obtained, the work is carried out to his satisfaction and the final dimensions are acceptable.

The repair of defects by welding is not permitted.

Identification

1209 (*a*) The manufacturer is to adopt a system of identification which will enable all finished material to be traced through all stages to the original cast and the Surveyors are to be given full facilities for so tracing the material when required.

TABLE P 12.3

Grade	AL 1	AL 2
0,2% Proof Stress kg/mm^2 minimum	12,5	20,0
Tensile Strength kg/mm^2 ,,	27,0	27,0
Elongation (on $5{,}65\sqrt{S_0}$) per cent minimum	11	8
(on 50 mm) per cent ,,	12	8

or in British Units:—

Grade	AL 1	AL 2
0·2% Proof Stress ton/in^2 minimum	7·9	12·7
Tensile Strength ton/in^2 ,,	17·1	17·1
Elongation (on $5{\cdot}65\sqrt{S_0}$) per cent minimum	11	8
(on 2 in) per cent ,,	12	8

(*b*) Before any item is finally accepted, it is to be clearly marked by the manufacturer in at least one place with the following particulars:—

(1) The Society's brand ,
(2) The manufacturer's name or trade mark,
(3) Identification mark for the grade of alloy,
(4) Identification mark which will enable the full history of the item to be traced,
(5) Purchaser's identification mark if required by the purchaser.

Hard stamping is to be used except when this may be detrimental to the material, when stencilling, painting or electric etching may be used.

Where a number of identical items are securely fastened together in bundles, subject to the agreement of the Surveyor, the manufacturer may brand only the top piece of each bundle, or alternatively, a durable label giving the required particulars may be attached to each bundle.

(*c*) When material is marked with the Society's brand prior to completion of mechanical tests and is subsequently rejected, the Surveyor is to ensure that all these marks are effectively defaced.

Documentation

1210 (*a*) The Surveyor shall be supplied with at least two copies of the mill sheets or shipping statements of all accepted material and these documents should be separate for each grade of aluminium alloy. The documents should contain, in addition to the description, dimensions, etc., of the material, the following particulars:—

(i) Purchaser's name.
(ii) Manufacturer's name.
(iii) Identification mark which will enable the full history of the item to be traced.
(iv) Identification of grade of alloy.
(v) Chemical composition.
(vi) Details of heat treatment (where applicable).
(vii) Order or ship number for which intended.

(*b*) Before the mill sheets or shipping statements are signed by the Surveyor, the manufacturer is required to furnish him with a certificate stating that the material has been made in accordance with the requirements of this Section and that it has been subjected to, and has withstood satisfactorily, the required tests in the presence of the Surveyor or his authorised deputy. The following form of certificate will be accepted if stamped or printed on each mill sheet with the name of the works and initialled for the manufacturers by an authorised official:—

> "We hereby certify that the material herein described has been made in accordance with the Rules of Lloyd's Register of Shipping for Grade............ aluminium alloy, and is that which has been tested in the presence of the Society's representative with satisfactory results."

(*c*) Where the alloy is not produced at the works at which it is wrought, a certificate is to be supplied to the Surveyor at the fabricating plant stating the name of the manufacturer, the cast number, identification and the chemical composition. The works at which the alloy was produced must be approved by the Committee.

Section 13

ALUMINIUM ALLOY RIVETS

1301 Aluminium alloy rivets intended for use in hull construction are to be manufactured and tested in accordance with P 12 except as undernoted.

Chemical Composition

1302 The chemical composition of bars used for the manufacture of rivets is to comply with the requirements of Table P 13.1.

Bar Material

1303 (*a*) All bar material intended for the manufacture of rivets is to be tested.

(*b*) Material of the same diameter, produced in the same way and of the same chemical composition, shall be grouped into batches not exceeding 250 kg (0·25 ton) in weight. At least one test sample is to be taken from a coil or length from each batch and is to be suitably heat treated prior to the preparation of mechanical test pieces. Test samples from Grade AL 3 alloy are to be annealed and from Grade AL 4 alloy solution treated.

(*c*) One tensile and one dump test piece are to be prepared from each test sample.

(*d*) The results of all tensile tests are to comply with the values given in Table P 13.2.

(*e*) Test pieces of a length and diameter equal to the full diameter of the bars shall, when cold, withstand being compressed without cracking until the diameter is increased to 1,6 times the original diameter.

TABLE P 13.1

Grade	AL 3	AL 4
Copper	0,10% max.	0,10% max.
Magnesium	3,0–3,9%	0,4–1,4%
Silicon	0,5% max.	0,6–1,6%
Iron	0,5% max.	0,5% max.
Manganese	0,6% max.	0,2–1,0%
Zinc	0,2% max.	0,2% max.
Chromium	0,35% max.	0,35% max.
Titanium and other grain refining elements	0,2% max.	0,2% max.
Aluminium	The remainder	The remainder

Manufactured Rivets

1304 (*a*) Rivets manufactured of the grade AL 3 alloy are to be supplied in the annealed condition while rivets of grade AL 4 alloy are to be supplied in the solution treated condition.

(*b*) From each consignment of manufactured rivets, at least three samples are to be selected for the dump test as described in 1303 (e).

Section 14

WELDING OF ALUMINIUM ALLOYS

1401 For general requirements where welding is employed, *see* D 3221.

1402 Grade AL 1 aluminium alloys are to be welded by the metal inert gas or tungsten inert gas processes. Where it is proposed to use other welding processes, details are to be submitted for approval.

Grade AL 2 aluminium alloys are not generally suitable for welded construction.

1403 The chemical composition of filler wire used in welding is to conform to the following requirements:—

Copper	... 0,10 per cent max.
Magnesium... ...	... 4,5 – 5,5 per cent
Silicon	... 0,6 per cent max.
Iron...	... 0,5 „ „ „
Manganese	... 1,0 „ „ „
Zinc...	... 0,2 „ „ „
Chromium	... 0,4 „ „ „
Titanium and other grain refining elements	... 0,2 „ „ „
Aluminium... ...	... The remainder.

TABLE P 13.2

Grade	0,2% Proof Stress Minimum kg/mm²	Tensile Strength Minimum kg/mm²	Elongation: On $5,65\sqrt{S_o}$ Minimum %	Elongation: On 50 mm (2 in) Minimum %	British Units: 0·2% Proof Stress Minimum ton/in²	British Units: Tensile Strength Minimum ton/in²
AL 3	9	22	18	16	5·8	14·0
AL 4	12	19	16	14	7·8	12·4

23rd July, 1970

Chapter Q

MATERIALS FOR BOILER, PRESSURE VESSEL AND MACHINERY CONSTRUCTION

Note :—For list of steel manufacturers see Appendix following this Chapter

General

Materials used in the construction of boilers, pressure vessels and machinery are to be manufactured and tested in accordance with the requirements contained in the following sections of this Chapter:—

Section 1. General requirements for Steel Plates, Sections, Bars, Castings, Forgings, Tubes and Pipes,
" 2. Dimensions of test pieces and methods of test,
" 3. Rolled steel plates,
" 4. Rolled steel sections and bars,
" 5. Steel castings,
" 6. Steel forgings,
" 7. Steel tubes and pipes,
" 8. Cast iron crank shafts,
" 9. Copper alloy propellers and propeller blades.

Where material is required to have guaranteed properties at low or high temperature, the reference temperature for testing purposes is to be stated. This reference temperature is generally to be selected from those tabulated in the Sections giving specific requirements.

Section 1

GENERAL REQUIREMENTS

Scope

101 (*a*) General requirements for Steel Plates, Sections, Bars, Castings, Forgings, Tubes and Pipes intended for use in the construction of boilers, pressure vessels and machinery.

These items are to be manufactured and tested in accordance with the requirements given in this Section and Q 2, together with the specific requirements contained in the relevant Sections Q 3 to Q 7.

Approval of Works

(*b*) Steel is to be manufactured at works approved by the Committee. A list of approved manufacturers is given in the appendix at the end of this Chapter.

Orders for Materials

(*c*) The order is to specify the required grade and condition of the material and the purpose for which it is intended.

Manufacture

102 (*a*) Steel is to be manufactured by the open-hearth, electric furnace or oxygen processes or by other processes approved by the Committee. An oxygen process is defined as a process in which molten iron contained in a basic lined converter is refined by directing a jet of high purity gaseous oxygen on to the surface of the hot metal.

The steel-making practice is to be such as to minimise the included non-metallic content of the finished steel. Acceptable deoxidation practices are given under the specific requirements in subsequent Sections of this Chapter.

(*b*) The steel is to be cast in metal ingot moulds or by an approved continuous casting process. The size of the ingot or of the continuous cast billet or slab is to be proportional to the dimensions of the final product in order that the amount of mechanical work will be adequate to ensure a satisfactory steel structure in the finished product. Provision is also to be made for sufficient discard to be taken from the top and bottom of each ingot to ensure soundness in the portion used for further processing. Periodically, and at the Surveyor's discretion, sulphur prints or other suitable proving tests may be required to demonstrate that this has been fulfilled.

(*c*) For certain important components it is required that the method of manufacture, or processing, be specially approved. When this condition applies, it is stated in the relevant specific requirements, and all necessary details are to be submitted for approval before production commences.

Chemical Analysis

103 The chemical composition is to be determined by the makers in an adequately equipped and competently staffed laboratory on samples taken from each ladle of each cast. The maker's analysis will be accepted but may be subject to occasional checks if required by the Surveyors.

Heat Treatment

104 All materials are to be supplied in the condition specified, or permitted, in the relevant Sections of this Chapter. Acceptable heat treatment processes and temperatures are detailed in the specific requirements. Where it is proposed to use a controlled rolling procedure, full details are to be submitted for approval.

Items normally supplied in the "as rolled" or "as drawn" condition may be subjected to a heat treatment proposed by the manufacturer for the purpose of obtaining the specified test results. Where material is supplied in the "as rolled" condition for subsequent re-working, e.g. plates for hot forming, billets for re-forging, etc., the manufacturer is to carry out any heat treatment which may be necessary to prevent hydrogen cracking or to make the material in a safe condition for transit. The proposed heat treatment is to be agreed by the Surveyor.

Heat treatment is to be carried out in properly constructed furnaces which are efficiently maintained and have adequate means for temperature control and are fitted with pyrometers which measure the temperature of the furnace charge. The furnace dimensions must permit the whole item being uniformly heated to the necessary temperature. In the case of very large structures which require heat treatment, alternative methods will be specially considered.

Test Material

105 (*a*) Sufficient test material is to be provided for the preparation of the tests detailed in the specific requirements. It is, however, in the interests of manufacturers to provide additional material for any retests which may be necessary, as insufficient or unacceptable test material may be a cause for rejection.

The test material is to be representative of the item, piece or batch. Cold straightening of test material may be carried out when permitted in the specific requirements, but otherwise the material is not to be re-worked or mechanically treated in any way which may influence the properties. Generally, test material is not to be removed from the item or piece until all heat treatment has been completed, except where an alternative procedure has been specially approved or where provision is made in the specific requirements for a simulated stress relieving, or blank carburising heat treatment.

All test material is to be selected and identified by the Surveyor or an authorised deputy. These identification marks are to be maintained during the preparation of the test pieces. Dimensions of test pieces are to be in accordance with Q 2.

Definitions

(*b*) *Piece or rolled length* in respect of plates, bars and sections, is the rolled product from a single slab, bloom or ingot if this is rolled directly into plates, bars or sections.

Item is a single plate, bar, section or component as delivered.

Test material or test block is the material from which the test piece is prepared.

Test piece is the portion of the test material or test block on which the actual test is carried out.

Mechanical Tests

106 (*a*) All prescribed mechanical tests are to be carried out by the manufacturer before the material is despatched and unless otherwise agreed they are to be witnessed by the Surveyor.

Test methods are to be in accordance with the procedures detailed in Q 2 and the results of all tests are to comply with the specific requirements given in subsequent sections.

The tests are to be carried out by competent personnel on machines of approved types. The machines are to be maintained in a satisfactory and accurate condition and are to be re-calibrated at approximately annual intervals. This calibration is to be carried out by a nationally recognised authority or other organisation of standing and is to be to the satisfaction of the Surveyor. A record of all calibrations is to be kept available in the test house.

Re-tests

(*b*) Where either the tensile test or the bend test, or both, fail and the Surveyor considers the fractured test piece or test pieces, or the results obtained therefrom, do not fairly represent the quality of the item or batch, two further test pieces of the same type are to be taken for each original test that failed. These additional tests are to be prepared from material adjacent to the original tests. In such cases the quality of the item or batch is to be judged by the result of the re-tests and not by the original test or tests which failed.

When a test covering a batch of material fails and one, or both, of the re-tests fail then the item or piece from which the tests were prepared is to be rejected. At the discretion of the Surveyor further pieces of the same type may be selected from the remaining material in the batch for testing in accordance with the specified requirements.

In the event of failure to meet impact test requirements, additional tests will only be permitted provided the average result was not less than 85 per cent of the required value. These additional tests are to consist of either three

Charpy U- or V-notch test pieces or one Izod test piece, as appropriate, cut from material adjacent to the original tests. The results are to be added to the original results and the material is acceptable if the new average value complies with the specified minimum average value.

Re-heat Treatment

(*c*) At the option of the manufacturer, when material which is intended to be supplied in the "as rolled" or "as drawn" condition fails test, it may be heat treated and re-submitted for test. The heat treatment may be either normalising, normalising and tempering, or as otherwise specially agreed.

When material is tested in the heat treated condition and fails test, it may be tempered or re-tempered and re-submitted for test. It may also be re-heated for normalising or quenching, provided it is not heated above the upper critical temperature more than three times, i.e. original and two re-treatments.

Alternatively, material which has failed test may be re-submitted as another grade.

Inspection

107 (*a*) The manufacturers shall afford the Surveyors all necessary facilities and access to all relevant parts of the works to enable them to verify that the approved process is adhered to, for the selection of test material, the witnessing of tests and the examination of material as required by the Rules.

(*b*) Surface inspection, verification of dimensions and, where appropriate, non-destructive examination are the responsibility of the manufacturer and are to be carried out on all material prior to despatch.

Witnessing of these tests by the Surveyor will be at his discretion except where this is included in the specific requirements or where specially requested by the purchaser.

Materials are to be free from segregations, flaws and laminations of such a nature as would be harmful in service. The surface finish is to be in accordance with good practice and surfaces are not to be hammered, peened or treated in any way that may invalidate the surface examination.

Slight surface imperfections may be removed by mechanical means, provided that after such treatment the dimensions are acceptable and the rectification has been completed to the satisfaction of the Surveyor.

When there is visible evidence to doubt the soundness of any material or component, such as flaws in test pieces or suspicious surface marks, the manufacturer is expected to prove the material by any suitable method.

In the event of any material proving unsatisfactory during subsequent working, machining or fabricating, such material is to be rejected notwithstanding any previous certification.

Non-destructive Testing

(*c*) The techniques employed are to be in accordance with recognised good practice, including any necessary surface preparation and are to be carried out by competent personnel using reliable and efficiently maintained equipment. The term "magnetic particle examination" is intended to imply inspection for surface flaws using suitable magnetic methods, but when this is not practicable a suitable dye penetrant method may be used instead.

Repair of Defective Material

108 The repair of defects by welding is not acceptable unless the agreement of the Surveyor is obtained before the work is commenced. Repair by welding cannot be considered unless it is permitted by the specific requirements of the relevant Section in this Chapter. When a repair has been agreed it is necessary in all cases to prove by suitable methods of inspection that the defects have been completely removed before welding is commenced. Welding procedures, including pre-heating, post-weld heat treatment and inspection are to be to the complete satisfaction of the Surveyor. In all cases, the area is to be magnetic particle tested on completion of welding, heat treatment and surface grinding.

Identification of Material

109 (*a*) The manufacturer is to adopt a system of identification which will enable all finished material to be traced to the original cast and the Surveyors are to be given full facilities for so tracing the material when required. When any item has been identified by the personal mark of a Surveyor, or his deputy, this is not to be removed until an acceptable new mark has been made. Failure to comply with this condition will render the item liable to rejection.

(*b*) Before any item is finally accepted it is to be clearly marked by the manufacturer in at least one place. The following particulars are to be shown:—

Plates, Bars and Sections

1. The Society's brand ,
2. The manufacturer's name or trade mark,
3. Identification mark for the grade of steel,
4. Identification mark which will enable the full history of the item to be traced,
5. Purchaser's identification mark if required by the purchaser.

Castings, Forgings, Tubes and Pipes

1. "L.R." or "Lloyds" and the abbreviated name of the Society's local office,
2. Identification mark which will enable the full history of the item to be traced,
3. Date of final inspection,
4. Personal stamp of Surveyor responsible for the final inspection.

Hard stamping is to be used except when this may be detrimental to the material, when stencilling, painting or electric etching may be used. Paints used for identifying alloy steels are to be free from lead, copper, zinc or tin.

Where a number of identical items are securely fastened together in bundles, subject to the agreement of the Surveyor the manufacturer may brand only the top piece of each bundle, or alternatively, a durable label giving the required particulars may be attached to each bundle.

(*c*) When material is marked with the Society's brand LR, "L.R.," "Lloyds" or the personal stamp of the Surveyor prior to completion of mechanical tests and is subsequently rejected, the Surveyor is to ensure that all these marks are effectively defaced.

Documentation

110 The manufacturer is to provide the Surveyor with a written statement giving the steelmaking process, cast number, cast analysis, mechanical test results and general details of heat treatment used for each item together with full particulars of the purchaser, order number and description.

When steel is not produced at the works at which it is rolled or forged, a certificate is to be supplied to the Surveyor at the rolling mill, forge or tube mill stating the process by which the steel was manufactured, the name of the steelmaker, the cast number, identification and ladle analysis. The works at which the steel was produced must be approved by the Committee.

Section 2

DIMENSIONS OF TEST PIECES AND METHODS OF TEST

Tensile Test Pieces

201 (*a*) Proportional test pieces for tensile tests with a gauge length of $5{,}65\sqrt{So}$, where So is the cross-sectional area of the test length, have been adopted as the standard form of test piece and in subsequent Sections of this Chapter, the minimum percentage elongation values are given for test pieces of these proportions. For reference purposes the test piece is to be machined to a diameter of 14 mm (0·564 in) with a gauge length of 70 mm (2·80 in). The minimum length of the parallel test length is to be 80 mm (3·15 in) and the ends may be machined in a form suitable for the grips of the testing machine provided there is an adequate radius between the test length and the enlarged ends.

(*b*) For routine testing purposes round machined test pieces with other diameters and gauge lengths may be used, subject to any requirements for minimum diameter or cross-sectional area given in subsequent Sections. Any of the test pieces detailed below may also be used for routine testing purposes. In all cases where the gauge length used is other than $5{,}65\sqrt{So}$ the equivalent percentage elongation is to be calculated using the formulæ or Tables given in 202.

Square or Rectangular Non-Proportional Tensile Test Pieces

(*c*) These are to be machined to a minimum width of 25 mm (1 in) and are to be the full thickness of the material with the rolled surfaces retained. The gauge length is to be 200 mm (8 in) and the minimum length of the parallel section is to be 225 mm (9 in). For rectangular sections the ratio of the sides is not to exceed 4:1. The ends may be machined to a greater width to suit the grips of the testing machine, provided there is an adequate radius between the test length and enlarged ends.

Full-Section Tensile Test Pieces

(*d*) Test samples from bars and other small rolled sections may be tested in full section. The cross-sectional area is to be calculated either from accurate measurement of the average dimensions or by determining the weight of a known length.

Tensile Pieces from Tubes and Pipes

(*e*) Samples from tubes and pipes may be tested in full section as above, provided the ends are plugged and the length of the test piece between the grips is at least 50 mm (2 in) greater than the gauge length.

Alternatively, test pieces may be prepared from strips cut longitudinally from the tubes or pipes. These test pieces are to be machined to a minimum width of 12 mm (0·5 in) but the ends may be machined to a greater width to suit the grips of the machine, provided there is an adequate radius between the test length and the enlarged ends. The central test length is not to be flattened but the enlarged ends may be flattened for gripping in the testing machine. The gauge length is to be 50 mm (2 in) and the minimum length of the parallel portion is to be 60 mm (2·4 in).

The cross-sectional area of this type of test piece having parallel edges is to be calculated as follows:—

$So = a\,b$

where So = cross-sectional area,

a = average radial thickness,

b = average width.

For thick walled pipes, the test material may be cut in either a longitudinal or circumferential direction and machined round test pieces prepared.

Equivalent Elongation

202 When a gauge length other than $5{,}65\sqrt{So}$ is used, the equivalent percentage elongation value is to be calculated using the following formula:—

$$E = \frac{n}{2}\left[\frac{Lo}{\sqrt{So}}\right]^{0{,}40}$$

where n = actual measured percentage elongation of test piece,

So = actual cross-sectional area of test piece,

Lo = actual gauge length of test piece,

E = equivalent percentage elongation for a test piece with a gauge length of $5{,}65\sqrt{So}$.

Alternatively, where a number of test pieces of similar material and dimensions are involved the actual percentage elongation values may be recorded, provided the equivalent specified minimum elongation value appropriate for the test piece dimensions is calculated from the above formula and is recorded on the test sheet.

For proportional test pieces having a gauge length other than $5{,}65\sqrt{So}$ the equivalent elongation may be calculated using the following factors:—

Actual gauge length	*Factor for equivalent elongation on* $5{,}65\sqrt{So}$
$4\sqrt{So}$	×0,870
$8{,}16\sqrt{So}$	×1,158
$11{,}3\sqrt{So}$	×1,317
$4d$	×0,916
$8d$	×1,207

For non-proportional test pieces with gauge lengths of 50 mm (2 in) and 200 mm (8 in) the equivalent elongation may be determined from Tables Q 2.1 and Q 2.2.

The above conversions are only reliable for carbon and carbon-manganese steels with a tensile strength not exceeding 70 kg/mm² (44 ton/in²) in the hot rolled, annealed, normalised or normalised and tempered conditions.

For alloy steels in the oil hardened and tempered condition, the following conversion may be used for proportional test pieces with a gauge length of $4\sqrt{So}$.

Actual percentage elongation on $4\sqrt{So}$	*Equivalent elongation on* $5{,}65\sqrt{So}$
22	17
20	15
18	13
17	12
16	12
15	11
14	10
12	8
10	7
8	5

For the following materials, the acceptance of any proposed conversion factor is to be at the discretion of the Surveyor:—

(i) Carbon and carbon-manganese steels with a tensile strength exceeding 70 kg/mm² (44 ton/in²),

(ii) Alloy steels in the normalised or normalised and tempered condition,

(iii) Cold worked steels,

(iv) Austenitic steels,

(v) Non-ferrous alloys.

Discarding of Tensile Test Pieces

203 Where the specified minimum percentage elongation is not obtained and the distance between the fracture and nearer gauge mark is less than one third of the original gauge length, the test piece is to be discarded. A further test piece is to be prepared and the quality of the material is to be judged entirely on the results obtained from this additional test.

Tensile Tests at Ambient Temperature

204 (*a*) The yield phenomena is not exhibited by all the materials specified in subsequent Sections of this Chapter but, for simplification, reference is only made to yield stress. Where no distinct yield is observed this is to be interpreted as either the 0,2 per cent proof stress or the 0,5 per cent proof stress under load.

(*b*) The yield stress is to be calculated from either:—

Beam Machines. The load immediately prior to a distinct drop in the testing machine lever,

Indicating Machines. The load immediately prior to a fall back in the movement of the pointer or the load at a marked hesitation of the pointer.

(*c*) The 0,2 per cent proof stress is to be determined from an accurate load/extension diagram by drawing a line parallel to the straight elastic portion and distant from it by an amount representing 0,2 per cent of the extensometer gauge

TABLE Q 2.1

Equivalent elongation on $5{,}65\sqrt{So}$ for test pieces with gauge lengths of 50 mm

Actual per cent. elong. on 50 mm gauge length	Corresponding per cent. elongation on $5{,}65\sqrt{So}$ gauge length if cross-sectional area in mm² is:—											
	50	100	150	200	300	400	500	600	700	800	900	1000
18	20	17	16	15	14	13	12	12	12	11	11	11
19	21	18	17	16	15	14	13	13	12	12	12	11
20	22	19	18	17	15	14	14	13	13	13	12	12
21	23	20	19	18	16	15	15	14	14	13	13	13
22	24	21	20	18	17	16	15	15	14	14	14	13
23	25	22	20	19	18	16	16	15	15	15	14	14
24	26	23	21	20	18	17	17	16	16	15	15	15
25	27	24	22	21	19	18	17	17	16	16	15	15
26	28	25	23	22	20	19	18	17	17	16	16	16
27	29	26	24	23	21	20	19	18	18	17	17	16
28	31	27	25	23	22	20	19	19	18	18	17	17
29	32	28	26	24	22	21	20	19	19	18	18	18
30	33	29	27	25	23	22	21	20	19	19	19	18
31	34	30	27	26	24	23	21	21	20	20	19	19
32	35	31	28	27	25	23	22	21	21	20	20	19
33	36	32	29	28	25	24	23	22	21	21	20	20
34	37	33	30	28	26	25	24	23	22	22	21	21
35	38	33	31	29	27	25	24	23	23	22	22	21
36	39	34	32	30	28	26	25	24	23	23	22	22
37	40	35	33	31	28	27	26	25	24	23	23	22
38	42	36	34	32	29	28	26	25	25	24	23	23
39	43	37	35	33	30	28	27	26	25	25	24	24
40	44	38	35	33	31	29	28	27	26	25	25	24
41	45	39	36	34	32	30	28	27	27	26	25	25
42	46	40	37	35	32	30	29	28	27	27	26	25
43	47	41	38	36	33	31	30	29	28	27	27	26
44	48	42	39	37	34	32	30	29	28	28	27	27
45	49	43	40	38	35	33	31	30	29	28	28	27
46	50	44	41	38	35	33	32	31	30	29	28	28
47	51	45	42	39	36	34	33	31	30	30	29	28

or in British units:—

TABLE Q 2.1

Equivalent elongation on $5 \cdot 65\sqrt{So}$ for test pieces with gauge lengths of 2 in

Actual per cent. elong. on 2 in gauge length	Corresponding per cent. elongation on $5 \cdot 65\sqrt{So}$ gauge length if cross-sectional area in inches^2 is:—										
	0·05	0·10	0·20	0·30	0·40	0·50	0·60	0·70	0·80	0·90	1·0
18	22	19	16	15	14	14	13	13	12	12	12
19	23	20	17	16	15	14	14	13	13	13	13
20	24	21	18	17	16	15	15	14	14	13	13
21	25	22	19	18	17	16	15	15	14	14	14
22	26	23	20	18	17	17	16	16	15	15	15
23	28	24	21	19	18	17	17	16	16	15	15
24	29	25	22	20	19	18	18	17	17	16	16
25	30	26	23	21	20	19	18	18	17	17	17
26	31	27	24	22	21	20	19	18	18	18	17
27	32	28	25	23	21	20	20	19	19	18	18
28	34	29	26	24	22	21	20	20	19	19	19
29	35	30	26	24	23	22	21	21	20	20	19
30	36	31	27	25	24	23	22	21	21	20	20
31	37	32	28	26	25	24	23	22	21	21	20
32	38	33	29	27	25	24	23	23	22	22	21
33	40	34	30	28	26	25	24	23	23	22	22
34	41	36	31	29	27	26	25	24	23	23	22
35	42	37	32	29	28	27	26	25	24	24	23
36	43	38	33	30	29	27	26	26	25	24	24
37	44	39	34	31	29	28	27	26	26	25	24
38	46	40	35	32	30	29	28	27	26	26	25
39	47	41	36	33	31	30	29	28	27	26	26
40	48	42	36	34	32	30	29	28	28	27	26
41	49	43	37	34	33	31	30	29	28	28	27
42	50	44	38	35	33	32	31	30	29	28	28
43	52	45	39	36	34	33	31	30	30	29	28
44	53	46	40	37	35	33	32	31	30	30	29
45		47	41	38	36	34	33	32	31	30	30
46		48	42	39	36	35	34	33	32	31	30
47		49	43	39	37	35	34	33	32	32	31

TABLE Q 2.2

Equivalent elongation on $5{,}65\sqrt{So}$ for test pieces with gauge lengths of 200 mm

Actual per cent. elong. on 200 mm gauge length	Corresponding per cent. elongation on $5{,}65\sqrt{So}$ gauge length if cross-sectional area in mm² is:—														
	100	150	200	300	400	500	600	700	800	900	1000	1500	2000	2500	3000
10	17	15	14	13	13	12	11	11	11	11	10	10	9	9	8
11	18	17	16	15	14	13	13	12	12	12	11	11	10	10	9
12	20	18	17	16	15	14	14	13	13	13	13	12	11	10	10
13	22	20	19	17	16	16	15	15	14	14	14	13	12	11	11
14	24	21	20	19	18	17	16	16	15	15	15	14	13	12	12
15	25	23	22	20	19	18	17	17	16	16	16	15	14	13	13
16	27	25	23	21	20	19	18	18	18	17	17	16	15	14	14
17	29	26	25	23	21	20	20	19	19	18	18	17	16	15	14
18	30	28	26	24	23	22	21	20	20	19	19	18	17	16	15
19	32	29	27	25	24	23	22	21	21	20	20	18	17	17	16
20	34	31	29	27	25	24	23	23	22	21	21	19	18	18	17
21	35	32	30	28	27	25	24	24	23	23	22	20	19	18	18
22	37	34	32	29	28	27	26	25	24	24	23	21	20	19	19
23	39	35	33	31	29	28	27	26	25	25	24	22	21	20	20
24	40	37	35	32	30	29	28	27	26	26	25	23	22	21	20
25	42	38	36	33	32	30	29	28	28	27	26	24	23	22	21
26	44	40	38	35	33	31	30	29	29	28	27	25	24	23	22
27	45	41	39	36	34	33	31	30	30	29	28	26	25	24	23
28	47	43	41	38	35	34	33	32	31	30	29	27	26	25	24
29	49	45	42	39	37	35	34	33	32	31	30	28	27	25	25
30	50	46	43	40	38	36	35	34	33	32	31	29	28	26	25
31	52	48	45	41	39	37	36	35	34	33	33	30	28	27	26
32		49	46	43	40	39	37	36	35	34	34	31	29	28	27
33		51	48	44	42	40	38	37	36	35	35	32	30	29	28
34		52	49	46	43	41	40	38	37	36	36	33	31	30	29
35			51	47	44	42	41	40	38	38	37	34	32	31	30
36			52	48	45	43	42	41	40	39	38	35	33	32	31
37				50	47	45	43	42	41	40	39	36	34	32	31
38				51	48	46	44	43	42	41	40	37	35	33	32
39				52	49	47	45	44	43	42	41	38	36	34	33

or in British units:—

TABLE Q 2.2

Equivalent elongation on $5 \cdot 65\sqrt{So}$ for test pieces with gauge lengths of 8 in

Actual per cent. elong. on 8 in gauge length	Corresponding per cent. elongation on $5 \cdot 65\sqrt{So}$ gauge length if cross-sectional area in inches^2 is:—															
	0·10	0·20	0·30	0·40	0·50	0·60	0·70	0·80	0·90	1·0	1·2	1·4	1·6	1·8	2·0	3·0	4·0
10	18	16	15	14	13	13	12	12	12	11	11	11	10	10	10	9	9
11	20	18	16	15	15	14	14	13	13	13	12	12	12	11	11	10	10
12	22	19	18	17	16	15	15	14	14	14	13	13	13	12	12	11	10
13	24	21	19	18	17	17	16	16	15	15	14	14	14	13	13	12	11
14	25	22	20	19	18	18	17	17	16	16	15	15	15	14	14	13	12
15	27	24	22	21	20	19	19	18	18	17	17	16	16	15	15	14	13
16	29	26	23	22	21	20	20	19	19	18	18	17	17	16	16	15	14
17	31	27	25	23	22	22	21	20	20	19	19	18	18	17	17	16	15
18	33	29	26	25	24	23	22	22	21	21	20	19	19	18	18	17	16
19	35	30	28	26	25	24	23	23	22	22	21	20	20	19	19	18	17
20	36	32	29	28	26	26	25	24	23	23	22	21	21	20	20	18	17
21	38	34	31	29	28	27	26	25	25	24	23	23	22	21	21	19	18
22	40	35	32	30	29	28	27	26	26	25	24	24	23	22	22	20	19
23	42	37	34	32	30	29	28	28	27	26	25	25	24	23	23	21	20
24	44	38	35	33	32	31	30	29	28	28	27	26	25	25	24	22	21
25	45	40	37	34	33	32	31	30	29	29	28	27	26	26	25	23	22
26	47	42	38	36	34	33	32	31	31	30	29	28	27	27	26	24	23
27	49	43	40	37	36	34	33	32	32	31	30	29	28	28	27	25	24
28	51	45	41	39	37	36	35	34	33	32	31	30	29	29	28	26	24
29	53	46	42	40	38	37	36	35	34	33	32	31	30	30	29	27	25
30		48	44	41	40	38	37	36	35	34	33	32	31	31	30	28	26
31		50	45	43	41	40	38	37	36	36	34	33	32	32	31	29	27
32		51	47	44	42	41	39	38	38	37	35	34	33	33	32	30	28
33		53	48	45	43	42	41	40	39	38	37	35	34	34	33	30	29
34			50	47	45	43	42	41	40	39	38	36	36	35	34	31	30
35			51	48	46	45	43	42	41	40	39	38	37	36	35	32	31
36			53	50	47	46	44	43	42	41	40	39	38	37	36	33	32
37				51	49	47	46	44	43	42	41	40	39	38	37	34	33
38				52	50	48	47	46	45	44	42	41	40	39	38	35	34
39					51	50	48	47	46	45	43	42	41	40	39	36	35

length. The point of intersection of this line with the plastic portion of the diagram represents the proof load, from which the 0,2 per cent proof stress can be calculated.

(*d*) The 0,5 per cent proof stress under load is to be calculated from the load corresponding to a *total* extension of 0,5 per cent of the original gauge length. This extension is to be measured either by the use of a suitable extensometer or by dividers.

(*e*) In all cases the rate of increase of stress in the upper half of the elastic range and until the yield load has been reached is not to be greater than 1 kg/mm²/second (0·6 ton/in²/second). After reaching the yield load the rate of straining may be increased to a maximum of 40 per cent of the original gauge length per minute for the determination of the tensile strength.

Tensile Tests at Elevated Temperatures

205 Test pieces used for the determination of lower yield or 0,2 per cent proof stress at elevated temperatures are to have an extensometer gauge length of not less than 50 mm (2 in) and a cross-sectional area of not less than 65 mm² (0·10 in²). Where, however, the dimensions of the product or the test equipment available will not permit this size of test piece being used, the test piece is to be of the largest practicable dimensions.

For materials which show the yield phenomenon, the straining rate in the upper half of the elastic range and during determination of the lower yield stress is to be within the range of 0,1 per cent to 0,3 per cent of the gauge length per minute and should preferably be controlled by reference to a strain pacer or a strain rate meter with a time interval between measurements of strain not exceeding 6 seconds. As an alternative to the use of a strain pacer or a strain rate meter the rate of increase of stress in the elastic range equivalent to the above maximum straining rate may be calculated taking into account the characteristics of the testing machine, the cross-section and gauge length of the test piece. This calculated value can then be used to control the straining rate during testing.

When the 0,2 per cent proof stress is being determined the rate of increase of stress in the upper half of the elastic range and during determination of the proof stress is not to exceed 4 kg/mm²/minute (2·5 ton/in²/minute).

Bend Test Pieces

206 Test pieces for bend tests are to be sheared or machined to the following dimensions:—

Plates and Sections: Plate or section thickness with a minimum width of 35 mm (1·4 in). The rolled surfaces are to be retained.

Thick Plates: When the power of the available testing machine is insufficient to bend a test piece of the full thickness, two test pieces each 25 mm (1 in) thick by 35 mm (1·4 in) wide are to be machined. One rolled surface is to be retained on each test piece and this is to be the side tested in tension.

Forgings and Castings: To be machined to a rectangular section 25 mm (1 in) wide by 20 mm (0·75 in) thick. A subsidiary test piece 20 mm (0·75 in) wide by 10 mm (0·4 in) thick is permitted for higher tensile strength steel and tests from rotor forgings. For steel castings a test piece machined to 25 mm (1 in) diameter may also be used.

Rolled Bars: Bars up to and including 25 mm (1 in) diameter are to be tested in full section. For larger diameter bars either a round test piece 25 mm (1 in) diameter or a rectangular test piece 25 mm (1 in) wide by 20 mm (0·75 in) thick is to be machined.

Pipes: The bend test piece is to be cut as a circumferential strip of the full wall thickness and with a width of not less than 35 mm (1·4 in). For thick walled pipes the wall thickness may be reduced to 20 mm (0·75 in) by machining. The test piece is to be bent in the direction of the original curvature.

The sharp edges of all rectangular section bend test pieces may be removed by suitable mechanical means to a radius not exceeding 1,5 mm (0·06 in).

Procedure for Bend Tests

207 This test is to be carried out at ambient temperature and is to consist of bending the test piece by pressure or hammer blows round a suitable former. The diameter of the former and the required angle of bend are to be in accordance with the specific requirements for the material. When an angle of bend of 180° is required, the sides after bending are to be parallel and apart by a distance equal to the diameter of the former specified for the material.

The test is considered to be satisfactory if, after bending as above, the test piece is unbroken and free from cracks and in the case of rolled products is also free from laminations. Small cracks at the edges of rectangular test pieces are to be disregarded.

Impact Tests

208 Test pieces for impact tests are to be either of the Charpy V-notch, Charpy U-notch or Izod types as required in subsequent Sections giving specific requirements for different components and materials.

The test pieces are to be machined to the dimensions and tolerances given in Tables Q 2.3 and Q 2.4.

TABLE Q 2.3

Overall Dimensions and Tolerances for Impact Test Pieces

Designation	Nominal Dimension	Tolerance
CHARPY V-NOTCH AND U-NOTCH		
Length	55 mm	±0,60 mm
Width Standard	10 mm	±0,11 mm
Subsidiary Standard	7,5 mm	±0,11 mm
" "	5,0 mm	±0,05 mm
" "	2,5 mm	±0,05 mm
Thickness	10 mm	±0,11 mm
Distance of notch from end of test piece ...	27,5 mm	±0,42 mm
SQUARE IZOD		
Length Standard 3 notch	130 mm	minimum
2 notch	100 mm	minimum
1 notch	75 mm	minimum
Width	10 mm	±0,11 mm
Thickness	10 mm	±0,11 mm
Distance of notch from end of test piece and from adjacent notch	28 mm	±0,42 mm
ROUND IZOD		
Length Standard 3 notch	5·2 in	minimum
2 notch	4·1 in	minimum
1 notch	3·0 in	minimum
Diameter	0·45 in	±0·005 in
Distance of notch from end of test piece and from adjacent notch	1·1 in	±0·018 in

TABLE Q 2.4

Dimensions and Tolerances of Notch for all types of Impact Test Pieces

Designation	Charpy V-Notch and Izod		Charpy U-Notch	
	Nominal Dimension	Tolerance	Nominal Dimension	Tolerance
Angle of notch	45°	±2°	—	—
Depth below notch ...	8 mm*	±0,11 mm	5 mm	±0,09 mm
Root radius	0,25 mm	±0,025 mm	1 mm	±0,07 mm
Angle between plane of symmetry of notch and the longitudinal axis of the test piece	90°	±2°	90°	±2°

*For round Izod test piece 0·32 in ±0·002 in

For material under 10 mm (0·4 in) in thickness, the largest possible size of subsidiary Charpy V-notch or U-notch is to be prepared with the notch cut on the narrow face. Generally, impact tests are not required when the thickness of the material is under 3 mm (0·12 in).

For 2 or 3 notch square Izod test pieces only one notch is to be cut on any one face. Notches on round Izod test pieces are to be similarly orientated.

Where Charpy V-notch or U-notch test pieces are taken from rolled products the notch is to be cut on the face of the test piece which was originally perpendicular to the rolled surface.

The impact test is to consist of either 3 Charpy V-notch or U-notch test pieces or one standard 3 notch Izod test piece (or equivalent 1 or 2 notch test pieces) as may be specified.

Charpy U-notch and Izod impact tests are generally to be carried out at ambient temperature. Charpy V-notch tests may be carried out at ambient or lower temperatures in accordance with the specific requirements given in subsequent Sections. Where the test temperature is other than ambient the temperature of the test pieces is to be controlled to within $\pm$ 2 degC for a sufficient time to ensure uniformity throughout the cross-section of the test piece and suitable precautions are to be taken to prevent any significant change in temperature during the actual test. In cases of dispute, ambient temperature is to be considered as 20 $\pm$ 2°C.

When reporting results the units used for expressing the energy absorbed and the actual testing temperature are to be clearly stated.

Flattening Test on Boiler Tubes and Pipes

209 The test piece is to consist of a piece of tube or pipe with the ends perpendicular to the axis. The length is to be equal to 1,5 times the nominal internal diameter but is to be not less than 10 mm (0·4 in) nor more than 100 mm (4·0 in). Alternatively, the test may be made on the end of a tube or pipe without the test piece being removed, provided that the length flattened is as above. The cut ends of the test piece may be rounded by filing.

The test is to be carried out at ambient temperature and is to consist of flattening the test piece in a direction perpendicular to the longitudinal axis of the pipe. Flattening is to be carried out between two plain parallel and rigid platens which extend over both the full length and the width after flattening of the test piece. Flattening is to be continued until the distance between the platens, measured under load, is not greater than that given in the specific requirements. After flattening the test piece is to be unbroken and free from cracks or other flaws. Small cracks at the ends of test pieces may be disregarded.

For electric resistance welded tubes or pipes the weld is to be placed at the line of maximum bending.

Drift Expanding Test on Boiler Tubes

210 The test piece is to consist of a piece of tube with one end cut perpendicular to the axis. The length is to be equal to 1,5 times the external diameter but not less than 50 mm (2 in). Alternatively, the test may be made on the end of a tube without the test piece being removed. The edges of the end to be tested may be rounded by filing.

The test is to be carried out at ambient temperature and is to consist of expanding the end of the tube symmetrically by means of a hardened conical steel mandrel having a total included angle of between 40° and 60° (*see* Fig. Q 2.1). The mandrel is to be forced into the test piece until the percentage increase in the external diameter of the end of the test piece reaches the value given in the specific requirements for boiler tubes. The mandrel is to be lubricated but there is to be no rotation of the tube or mandrel during the test.

The expanded portion of the tube is to be free from cracks or other flaws.

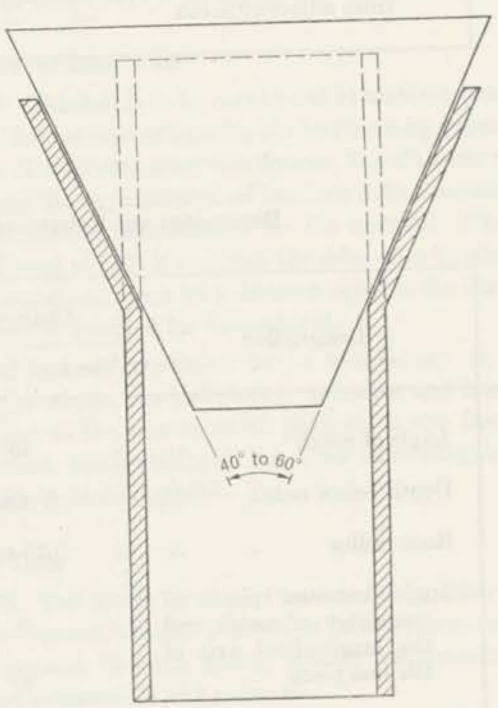


Fig. Q 2.1 Drift Expanding Test

Section 3

ROLLED STEEL PLATES

Scope

301 This Section gives specific requirements for carbon, carbon-manganese and low alloy steel plates intended for use in the construction of boiler or superheater drums or headers, pressure vessels and welded machinery structures. For pressure vessels containing radio-active materials or gases, additional requirements may be specified.

The steel plates are to be manufactured and tested in accordance with the requirements of this Section and the relevant requirements of Q 1 and Q 2. Provision is made for four categories of plates which differ mainly in respect of testing procedures and are intended for the following uses:—

Category I	For boilers and pressure vessels where design is based on guaranteed values for elevated temperature properties.
Category II(a)	For boilers and pressure vessels where design is based on nominal values for elevated temperature properties which are not required to be proved by test.
Category II(b)	For welded machinery structures.
Category III	For pressure vessels intended for special low temperature service where the steel is to have guaranteed low temperature Charpy V-notch impact properties. In this case the proposed specification is to be submitted for approval.

Alternatively, steel plates complying with national or proprietary specifications may be accepted provided these specifications give reasonable equivalence to the requirements of this Section.

Manufacture

302 For Categories I and II the method of de-oxidation is to be in accordance with that given in Table Q 3.1. For Category III the method of de-oxidation is to be included in the specification submitted for approval. Silicon killed or aluminium treated steels are to be cast in moulds with efficient feeder heads.

Chemical Composition

303 For Categories I or II the chemical composition of the steel is to comply with the requirements given in Table Q 3.1. This Table also gives details of the grades for each Category.

The chemical composition of steels for Category III is to comply with the approved specification.

Heat Treatment

304 All plates are to be supplied in the condition detailed in Table Q 3.2, unless otherwise agreed. For carbon and carbon-manganese steels an approved procedure for controlled rolling can be accepted instead of a normalising heat treatment. Plates intended for hot forming may be supplied in the "as rolled" condition provided that they are either hot formed in the normalising temperature range or are normalised after hot forming.

If required by the Surveyors or by the fabricator, test material may be given a simulated stress relieving heat treatment prior to the preparation of the test pieces. This has to be stated on the order together with agreed details of the simulated heat treatment and the mechanical properties which can be accepted.

Test Material

305 (*a*) *Category I.* Tensile tests at ambient temperature and bend tests are to be taken from one end of each rolled length when the weight is not in excess of 2500 kg (2·5 tons). When the weight exceeds 2500 kg (2·5 tons) these tests are to be taken from both ends.

For applications where the design temperature is in excess of 100° C one elevated temperature tensile test is to be taken from each rolled length. When the rolled length exceeds 2500 kg (2·5 tons) in weight the test piece is to be taken from the end which gave the lower tensile value at ambient temperature. These tensile tests at elevated temperatures are not required when:—

(i) the reference test temperature is 100°C or less,

or (ii) the specified minimum value of the 0,2 per cent proof stress value at the reference test temperature is higher than the corresponding stress-to-rupture value,

or (iii) the actual tensile strength at ambient temperature exceeds by at least 4 kg/mm^2 (2·5 ton/in^2) the specified minimum tensile strength. This applies only to carbon and carbon-manganese steels,

or (iv) the steelmaker has obtained certification of elevated temperature proof stress values, as detailed in 306(d).

Category II (*a*). Tensile tests at ambient temperature and bend tests are to be taken as for Category I. Tensile tests at elevated temperatures are not required.

Category II (*b*). One tensile test piece is to be taken from the thickest piece in each batch of 20 000 kg (20 tons) or less, from the same cast. Where the thicknesses of the pieces

TABLE Q 3.1

Chemical Composition of Plates, Categories I and II

Grade of Steel	Tensile Strength kg/mm^2	Tensile Strength ton/in^2	Category	Method of Deoxidation	Chemical Composition of Ladle Samples, Per Cent: C	Si	Mn	S	P	Residual Elements: Ni	Cr	Mo	Cu
Carbon and Carbon-Manganese	37–47	23·5–29·8	I, IIa, IIb	Any except rimming	0,17 max.	0,35 max.	0,40–1,20	0,050 max.	0,050 max.	Ni 0,30 max. Cr 0,25 max. Mo 0,10 max. Cu 0,30 max. Total 0,70 max.			
	42–52	26·7–33·0	I, IIa, IIb	Any except rimming	0,20 max.	0,35 max.	0,50–1,30	0,050 max.	0,050 max.				
	47–57	29·8–36·2	I, IIa	Any except rimming (Note 1)	0,20 max. (Note 2)	0,35 max.	0,60–1,40	0,050 max.	0,050 max.				
	52–62	33·0–39·4	I, IIa	Any except rimming (Note 1)	0,20 max. (Note 2)	0,50 max.	0,90–1,50	0,050 max.	0,050 max.				
					C	Si	Mn	S	P	Ni	Cr	Mo	Cu
Low Alloy 1Cr$\frac{1}{2}$Mo	44–56	27·9–35·6	I	Silicon killed	0,18 max.	0,15–0,35	0,4–0,8	0,040 max.	0,040 max.	0,30 max.	0,8–1,2	0,4–0,6	0,20 max.
2$\frac{1}{4}$Cr1Mo	52–67	33·0–42·5	I	Silicon killed	0,15 max.	0,15–0,35	0,4–0,8	0,040 max.	0,040 max.	0,30 max.	2,0–2,5	0,9–1,1	0,20 max.

NOTES: 1. May also contain Niobium 0,08 per cent max.

2. For material over 30 mm (1·2 in) in thickness Carbon 0,22 per cent max.

TABLE Q 3.2

Heat Treatment of Plates

Grade of Steel	Tensile Strength		Category I	Categories IIa & IIb	Category III
	kg/mm²	ton/in²			
Carbon and Carbon-Manganese	37–47	23·5–29·8	All thicknesses to be normalised	Plates exceeding 45 mm (1·75 in) in thickness to be normalised	In accordance with approved specification
	42–52	26·7–33·0			
	47–57	29·8–36·2	All thicknesses to be normalised	All thicknesses to be normalised	In accordance with approved specification
	52–62	33·0–39·4			
Low Alloy 1Cr½Mo	44–56	27·9–35·6	All thicknesses to be normalised (Note 1)		
2¼Cr1Mo	52–67	33·0–42·5	All thicknesses to be normalised and tempered		

Note 1. May also be normalised and tempered

within a batch vary by more than 12 mm (0·5 in) an additional test representing the thinner material is to be taken.

One bend test piece is to be taken from each rolled length.

Category III. Tensile tests at ambient temperature and bend tests are to be taken as for Category I and in addition a set of three Charpy V-notch test pieces is to be taken from one end of each rolled length.

(*b*) Test pieces for tensile tests at ambient and elevated temperatures and for bend tests are to be transverse to the principal direction of rolling and are to be cut from the plate end or ends at approximately quarter width. The axis of fully machined round proportional test pieces is, when the thickness permits, to be co-incident with the quarter thickness of the plate.

Impact test pieces are to be cut from a similar position but are to be parallel to the principal direction of rolling. They are to be machined from material close to one of the rolled surfaces.

(*c*) When plates are required for hot forming and it has been agreed that the heat treatment will be carried out by the fabricator then the tests at the steelworks are to be made on material which has been cut from the plates and given a normalising or normalising and tempering heat treatment in a manner simulating the treatment which will be applied to the plates.

(*d*) Cold straightening of material for tensile and impact tests is not permitted.

(*e*) All test pieces are to be machined in accordance with Q 2 and for tests at ambient temperature the tensile test pieces are to have a cross-sectional area of not less than 150 mm² (0·23 in²).

Mechanical Properties

306 (*a*) *Category I.* The results of all tensile tests are to comply with the values given in Table Q 3.3. The lower yield or 0,2 per cent proof stress values at elevated temperatures are to be determined at the reference test temperature given in the order (*see* Q 101(c)).

Bend test pieces are to withstand being bent through an angle of 180° round a former having a diameter not greater than that specified in Table Q 3.3.

Stress rupture values for design purposes are given in Table Q 3.5.

(*b*) *Category II.* The results of all tensile tests at ambient temperature are to comply with the values given in Table Q 3.4.

Bend test pieces are to withstand being bent through an angle of 180° round a former having a diameter not greater than that specified in Table Q 3.4.

For design purposes nominal values of the lower yield or 0,2 per cent proof stress at elevated temperatures are given in Table Q 3.4 for carbon and carbon-manganese steels. Stress rupture values are given in Table Q 3.5.

(*c*) *Category III.* The results of all the tensile, bend and impact tests are to comply with the approved specification. The Charpy V-notch tests are to be made at or below the reference test temperature given in the order (*see* Q 101(c)).

TABLE Q 3.3

Mechanical Properties of Plates, Category I

Grade of Steel	Yield Stress kg/mm^2 Minimum for thickness in mm. (Note 1)			Tensile Strength kg/mm^2	Elongation on $5{,}65\sqrt{So}$ % Minimum (Note 2)	Bend Test Maximum diameter of former	Minimum Lower Yield or 0,2% Proof Stress, kg/mm^2 (Note 1)										
	Up to 16	Over 16 to 40	Over 40 to 63				100° C	150° C	200° C	250° C	300° C	350° C	400° C	450° C	500° C	550° C	600° C
Carbon and Carbon-Manganese	24	23	22	37–47	25	2t	17,5	17,0	16,5	15,0	13,5	12,5	11,5	10,0			
	26	25	24	42–52	23	2t	21,0	20,5	19,5	18,0	16,0	15,0	14,0	12,0			
	30	29	28	47–57	21	3t	25,0	24,0	22,5	20,5	19,0	17,5	16,0	14,0			
	36	35	34	52–62	20	3t	29,0	28,0	26,0	24,0	22,0	20,5	18,0	16,0			
Low Alloy $1Cr\frac{1}{2}Mo$	29	28	28	44–56	23	3t	Values by agreement with the manufacturer										
$2\frac{1}{4}Cr1Mo$	32	31	31	52–67	18	3t											

t = thickness of bend test piece.

NOTES: 1. These values apply only to plates up to 63 mm in thickness. For thicker plates the yield stress or the 0,2 per cent proof stress values are to be reduced by 1 per cent for each 5 mm increase in thickness over 63 mm.

2. For plates over 63 mm in thickness the minimum percentage elongation values are to be reduced by 1.

or in British units:—

TABLE Q 3.3

Mechanical Properties of Plates, Category I

Grade of Steel	Yield Stress ton/in², Minimum for thickness in inches (Note 1)			Tensile Strength ton/in²	Elongation on $5{\cdot}65\sqrt{So}$ % Minimum (Note 2)	Bend Test Maximum diameter of former	Minimum Lower Yield or 0·2% Proof Stress $\frac{\text{ton/in}^2}{\text{lb/in}^2}$ (Note 1)										
	Up to 0·63	Over 0·63 to 1·6	Over 1·6 to 2·5				100° C	150° C	200° C	250° C	300° C	350° C	400° C	450° C	500° C	550° C	600° C
Carbon and Carbon-Manganese	15·2	14·6	14·0	23·5–29·8	25	2t	11·1 24 900	10·8 24 200	10·5 23 500	9·5 21 300	8·6 19 200	7·9 17 800	7·3 16 400	6·4 14 200			
	16·5	15·9	15·2	26·7–33·0	23	2t	13·3 29 900	13·0 29 200	12·4 27 700	11·4 25 600	10·2 22 800	9·5 21 300	8·9 19 900	7·6 17 100			
	19·1	18·4	17·8	29·8–36·2	21	3t	15·9 35 600	15·2 34 100	14·3 32 000	13·0 29 200	12·1 27 000	11·1 24 900	10·2 22 800	8·9 19 900			
	22·9	22·2	21·6	33·0–39·4	20	3t	18·4 41 200	17·9 39 800	16·5 37 000	15·2 34 100	14·0 31 300	13·0 29 200	11·4 25 600	10·2 22 800			
Low Alloy 1Cr½Mo	18·4	17·8	17·8	27·9–35·6	23	3t	Values by agreement with the manufacturer										
2¼Cr1Mo	20·3	19·7	19·7	33·0–42·5	18	3t											

t = thickness of bend test piece

Notes: 1. These values apply only to plates up to 2·5 inches in thickness. For thicker plates the yield stress or the 0·2 per cent proof stress values are to be reduced by 1 per cent for each 0·2 in increase in thickness over 2·5 in.

2. For plates over 2·5 inches in thickness the minimum percentage elongation values are to be reduced by 1.

TABLE Q 3.4

Mechanical Properties of Plates, Category II

Grade of Steel	Yield Stress kg/mm² Minimum for thickness in mm.			Tensile Strength kg/mm²	Elongation on 5,65 $\sqrt{So}$ % Minimum (Note 2)	Bend Test Maximum diameter of former	Lower Yield or 0,2 % Proof Stress kg/mm² (Note 1)										
	Up to 16	Over 16 to 40	Over 40 to 63				100° C	150° C	200° C	250° C	300° C	350° C	400° C	450° C	500° C	550° C	600° C
Carbon and Carbon-Manganese	21	20	19	37–47	25	2t	14,8	14,5	14,2	12,8	11,2	9,6	9,4	9,4			
	23,5	22,5	21,5	42–52	23	2t	18,0	17,6	17,3	15,8	14,2	12,6	12,3	12,0			
	26,5	25,5	24,5	47–57	21	3t	21,0	20,8	20,3	18,6	17,0	15,4	14,5	13,5			
	30	29	28	52–62	20	3t	24,1	23,8	23,1	21,4	19,9	18,3	16,5	15,0			

t = thickness of bend test piece

NOTES: 1. The values for yield stress or 0,2 per cent proof stress at elevated temperatures are given for design purposes and do not have to be proved by test.

2. For plates over 63 mm in thickness the minimum percentage elongation values are to be reduced by 1.

or in British units:—

TABLE Q 3.4

Mechanical Properties of Plates, Category II

Grade of Steel	Yield Stress ton/in² Minimum for thickness in inches			Tensile Strength ton/in²	Elongation on 5·65 $\sqrt{So}$ % Minimum (Note 2)	Bend Test Maximum diameter of former	Lower Yield or 0·2 % Proof Stress, lb/in² (Note 1)										
	Up to 0·63	Over 0·63 to 1·6	Over 1·6 to 2·5				100° C	150° C	200° C	250° C	300° C	350° C	400° C	450° C	500° C	550° C	600° C
Carbon and Carbon-Manganese	13·3	12·7	12·1	23·5–29·8	25	2t	21 100	20 600	20 200	18 200	15 900	13 700	13 400	13 400			
	14·6	14·3	13·6	26·7–33·0	23	2t	25 600	25 000	24 600	22 500	20 200	17 900	17 500	17 100			
	16·8	16·2	15·5	29·8–36·2	21	3t	29 900	29 600	28 900	26 500	24 200	21 900	20 600	19 200			
	19·1	18·4	17·9	33·0–39·4	20	3t	34 300	33 900	32 900	30 400	28 300	26 000	23 500	21 300			

t = thickness of bend test piece

NOTES: 1. The values for lower yield or 0·2 per cent proof stress at elevated temperatures are given for design purposes and do not have to be proved by test.

2. For plates over 2·5 inches in thickness the minimum percentage elongation values are to be reduced by 1.

TABLE Q 3.5

Average Values for Stress to Rupture in 100 000 hours, Categories I and II

Units: kg/mm²

Temperature °C	Carbon and Carbon-Manganese Steel	1Cr ½Mo Steel	2¼Cr 1Mo Steel
350	21,5		
360	19,7		
370	17,9		
380	16,0		
390	14,3		
400	12,5		
410	10,8		
420	9,4		
430	8,3		
440	7,3		
450	6,5	32,0	
460	5,7	28,4	
470	5,0	25,0	
480	4,4	21,6	21,4
490	3,8	18,3	19,2
500	3,3	15,1	17,2
510		12,4	15,1
520		10,1	13,2
530		8,0	11,5
540		6,3	9,9
550		5,0	8,5
560		4,1	7,2
570		3,2	6,1
580		2,4	5,2
590			4,4
600			3,8

or in British units:—

TABLE Q 3.5

Average Values for Stress to Rupture in 100 000 hours, Categories I and II

Units : lb/in^2

Temperature °C	Carbon and Carbon-Manganese Steel	1Cr ½Mo Steel	2¼Cr 1Mo Steel
350	30 600		
360	28 000		
370	25 400		
380	22 800		
390	20 300		
400	17 800		
410	15 300		
420	13 400		
430	11 800		
440	10 400		
450	9200	45 500	
460	8000	40 300	
470	7100	35 600	
480	6200	30 700	30 500
490	5400	26 000	27 300
500	4700	21 500	24 400
510		17 700	21 500
520		14 300	18 800
530		11 400	16 400
540		9000	14 100
550		7200	12 100
560		5800	10 300
570		4500	8700
580		3400	7400
590			6300
600			5400

Certification of Lower Yield or 0,2 per cent Proof Stress Values at Elevated Temperatures

(*d*) For Category I material and other approved grades, as an alternative to taking tensile tests at elevated temperatures from each plate, individual steelmakers may submit for analysis and approval comprehensive test data for a specific grade of steel to demonstrate the lower yield or 0,2 per cent proof stress values at elevated temperatures which can be consistently obtained. This data will be assessed on a statistical basis to determine the 95 per cent lower confidence limits. When a manufacturer is approved on this basis routine tensile tests at elevated temperatures will not be required except for periodic check tests at the discretion of the Surveyors.

Steelmakers requiring this form of certification are to submit the following information and test data from at least 45 plates taken from not less than 10 different casts for each grade of steel.

(1) Ladle analysis including residual elements,

(2) Method of de-oxidation,

(3) Details of heat treatment,

(4) Results of tensile tests at ambient temperature:— Yield stress, tensile strength and percentage elongation,

(5) Results of tensile tests at elevated temperatures:— Lower yield or 0,2 per cent proof stress values at 100, 150, 200, 250, 300, 350, 400, 450° C or higher if appropriate for the grade of steel being tested.

(6) Plate thickness.

The test data are to be representative of the tensile range specified for the grade and also the range of thickness which will be manufactured. For carbon and carbon-manganese steels where there is an overlap in the specified tensile strength range, data submitted for one grade may also be considered for adjacent grades provided the ambient temperature properties comply with the appropriate tensile strength range.

Inspection

307 Inspection is to be carried out in accordance with Q 107.

Repair of Defects

308 The repair of defects by welding at the steelworks is not accepted but proposals for the repair of minor surface defects by the fabricator in accordance with Q 108 will be considered.

Identification

309 Plates are to be identified in accordance with Q 109.

Documentation

310 The manufacturer is to supply the information detailed in Q 110.

Section 4

ROLLED STEEL SECTIONS AND BARS

Scope

401 (*a*) Hot rolled sections and bars intended for use in boiler, pressure vessel and machinery construction are to be manufactured and tested in accordance with the requirements of this Section and the relevant parts of Q 1 and Q 2.

These requirements are related to the intended application and have been sub-divided as follows:—

Rolled Steel Sections and Bars (Boiler Quality)

Paragraphs 402 to 410 give the requirements for rolled sections and bars intended for structural purposes. These include boiler stay bars and bars for the manufacture of bolts which are not subject to dynamic loading or to creep relaxation.

Rolled Steel Bars (Machinery Quality)

Paragraphs 412 to 420 give the requirements for rolled bars intended for the manufacture (by machining operations only) of straight shafting and other important components which are subject to significant dynamic stresses but not subject to creep relaxation. These requirements are applicable only to bars with a diameter not exceeding 250 mm (10 in) and larger items are to be manufactured and tested in accordance with Q 6.

Rolled Steel Bars (Rivet Quality)

Paragraphs 422 to 430 give the requirements for rolled bars intended for the production of rivets and also the tests required from manufactured rivets.

(*b*) Rolled bars intended for re-forging are to be manufactured in accordance with the requirements of Q 6 but mechanical tests are not required at the rolling mill.

(*c*) Bolts for turbine casings, steam pipe joints and other applications subject to creep relaxation are to be manufactured in accordance with an approved specification.

(*d*) In the case of sections and bars intended for special low temperature service, where the steel is to have guaranteed Charpy V-notch impact values at low temperatures, details of the proposed specification are to be submitted for approval.

(*e*) At the discretion of the Surveyor, a modified testing procedure may be adopted for small quantities of material.

In such cases short lengths may be accepted on the manufacturer's declared chemical composition and hardness tests or other evidence of satisfactory properties.

(*f*) Alternatively, steel sections complying with national or proprietary specifications may be accepted provided these specifications give reasonable equivalence to the requirements of this Section.

ROLLED STEEL SECTIONS AND BARS

(Boiler Quality)

402 Rimming or free-cutting steels are not permitted. Any other method of de-oxidation may be used except that for steel with guaranteed low temperature impact properties, the method of de-oxidation is to be in accordance with the approved specification.

Chemical Composition

403 The chemical composition is to comply with the requirements given in Table Q 4.1.

The chemical composition of steels for special low temperature service is to comply with the approved specification.

Heat Treatment

404 Sections and bars may, at the option of the manufacturer be supplied either in the "as rolled" or normalised condition.

Steels with guaranteed low temperature impact properties are to be heat treated in accordance with the approved specification.

Test Material

405 (*a*) Sections and bars are to be presented for testing in batches containing not more than 50 lengths or 10 000 kg (10 tons) whichever is less. The material in each batch is to be of the same section size and from the same cast. If the sections are supplied in the heat treated condition, the material in each batch is to be subjected to the same finishing treatment in a continuous furnace or heat treated in the same furnace charge in a batch type furnace.

At least one tensile test piece is to be taken from material representative of each batch. Bend test pieces are to be taken from each piece (*see* Q 105(b)).

When required, a set of three Charpy V-notch test pieces are to be taken from material representative of each batch.

(*b*) All test pieces are to be cut parallel to the direction of rolling. Any straightening of test pieces, which may be required, is to be done cold.

When required, Charpy V-notch impact test pieces are to be cut from the following positions:—

Flats, round and square bar:—	At approximately two-thirds radius from the axis of the flat or bar.
Angles and tees:—	On thickest leg approximately one-third from the outer edge.
Joists and channels:—	On thickest flange at approximately one-third from the outer edge.

Mechanical Properties

406 The results of all tensile tests are to comply with the values given in Table Q 4.2. Bend test pieces are to withstand being bent through an angle of 180° round a former having a diameter not greater than that specified in the above Table.

For steels intended for special low temperature service the Charpy V-notch tests are to be carried out at the reference test temperature given in the order (*see* Q 101(c)). The results of tensile, bend and Charpy V-notch impact tests are to comply with the approved specification.

Inspection

407 Inspection is to be carried out in accordance with Q 107.

Repair of Defects

408 The repair of defects by welding at the steelworks is not acceptable but proposals for the repair of minor surface defects by the fabricator in accordance with Q 108 will be considered.

Identification

409 Sections are to be identified in accordance with Q 109.

Documentation

410 The manufacturer is to supply the information detailed in Q 110.

ROLLED STEEL BARS

(Machinery Quality)

Scope

411 These requirements apply to rolled bars not exceeding 250 mm (10 in) diameter which are intended for the manufacture (by machining operations only) of straight shafting and other important components which are subject to significant dynamic stresses but not subject to creep relaxation.

Larger items are to be manufactured and tested in accordance with Q 6.

TABLE Q 4.1

Chemical Composition of Sections and Bars (Boiler Quality)

Grade of Steel	Tensile Strength		Chemical Composition of ladle samples—percentage					
	kg/mm^2	ton/in^2	C	Si	Mn	S	P	Residual Elements
Carbon and Carbon-Manganese	42–52	26·7–33·0	0,20 max.	0,35 max.	0,50–1,30	0,050 max.	0,050 max.	Ni 0,30 max. Cr 0,25 max. Mo 0,10 max. Cu 0,30 max. Total 0,70 max.
	47–57	29·8–36·2	0,20 max. (Note 1)	0,35 max.	0,60–1,40 (Note 2)	0,050 max.	0,050 max.	

NOTES: 1. For material over 30 mm (1·2 in) in thickness. Carbon 0,22 per cent max.

2. For sections used in welded machinery structures and for boiler stay bars, $C+\frac{Mn}{6}$ is not in general to exceed 0,41 per cent.

TABLE Q 4.2

Mechanical Properties of Sections and Bars (Boiler Quality)

Grade of Steel	Minimum Yield Stress kg/mm^2 for thickness or diameter in mm (Note 1)			Tensile Strength kg/mm^2	Elongation on $5{,}65\sqrt{So}$ % Minimum (Note 2)	Bend Test Max. diameter of former
	Up to 16	Over 16 to 40	Over 40 to 63			
Carbon and Carbon-Manganese	23,5	22,5	21,5	42–52	23	2t
	26,5	25,5	24,5	47–57	21	3t

t = thickness of bend test piece.

NOTES: 1. These values apply only to material with a thickness or diameter less than 63 mm. For material over 63 mm the yield stress values are to be reduced by 1 per cent for each 5 mm increase in thickness or diameter over 63 mm.

2. For material over 63 mm in thickness or diameter the minimum elongation values are to be reduced by 1.

or in British units:—

TABLE Q 4.2

Mechanical Properties of Sections and Bars (Boiler Quality)

Grade of Steel	Minimum Yield Stress ton/in^2 for thickness or diameter in inches (Note 1)			Tensile Strength ton/in^2	Elongation on $5·65\sqrt{So}$ % Minimum (Note 2)	Bend Test Max. diameter of former
	Up to 0·63	Over 0·63 to 1·6	Over 1·6 to 2·5			
Carbon and Carbon-Manganese	14·6	14·3	13·6	26·7–33·0	23	2t
	16·8	16·2	15·5	29·8–36·2	21	3t

t = thickness of bend test piece.

NOTES: 1. These values apply only to material with a thickness less than 2·5 in. For material over 2·5 in the yield stress values are to be reduced by 1 per cent for each 0·2 in increase in thickness or diameter over 2·5 in.

2. For material over 2·5 inches in thickness or diameter the minimum elongation values are to be reduced by 1.

Manufacture

412 Bars are to be manufactured in accordance with the requirements of Q 602. The use of rimming, free-cutting or semi-killed steel is not acceptable.

Chemical Composition

413 The chemical composition is to comply with the requirements of Q 603.

Heat Treatment

414 Bars are to be supplied in the normalised or other approved condition of heat treatment.

Test Material

415 Material is to be presented for test in batches. A batch is to consist of either:—

(i) material from the same piece or rolled length (*see* Q 105(b)) provided that where this is cut into individual lengths, these are all heat treated in the same furnace charge.

or (ii) bars of the same diameter and cast, heat treated in the same furnace charge and with a total weight not exceeding 1000 kg (1 ton).

One tensile and one bend test piece are to be taken from each batch, and are to be machined in accordance with Q 2.

Mechanical Properties

416 The results of all tensile tests are to comply with the requirements of Q 606. Bend test pieces are to withstand being bent through an angle of 180° round a former having a diameter not greater than that specified in Table Q 6.3.

Inspection

417 Inspection is to be carried out in accordance with Q 107.

Repair of Defects

418 The repair of defects by welding is not permitted.

Identification

419 The rolled bars are to be identified in accordance with Q 109.

Documentation

420 The manufacturer is to supply the information detailed in Q 110.

ROLLED STEEL BARS

(Rivet Quality)

Scope

421 These requirements apply to rolled bars intended for the production of rivets. The tests required for manufactured rivets are also given.

Manufacturer

422 The steel is to be non-rimming and is to be free from excessive central segregation.

Chemical Composition

423 The chemical composition is to comply with the following:—

Carbon	0,22% max.
Silicon	0,35% max.
Manganese	0,4/1,0%
Sulphur	0,050% max.
Phosphorus	0,050% max.

Heat Treatment

424 Bars and rivets are to be supplied in the "as rolled" or "as manufactured" condition.

Test Material

425 (*a*) Bars are to be presented for test in batches. A batch is to consist of bars rolled from one cast and the total weight of the batch is not to exceed 10 000 kg (10 tons).

From each batch one tensile test piece is to be selected and prepared in accordance with Q 2. In addition, one sample for sulphur print and one dump test piece is to be selected from each batch. The length of the dump test piece is to be equal to twice the diameter.

(*b*) From each consignment of manufactured rivets, at least three samples are to be selected for the bend and flattening tests described in 428 and for sulphur prints.

Mechanical Properties

426 The tensile test is to be made in accordance with Q 2 and is to give a value between 40 and 48 kg/mm² (25·4 and 30·5 ton/in²). The elongation is to be not less than 26 per cent.

Sulphur Prints

427 Sulphur prints for bars and from manufactured rivets are to show that the material is free from significant central segregation.

Dump, Bending and Flattening Tests

428 The dump test pieces are to withstand being compressed, when cold, to half their length without fracture.

Sample rivets are to withstand being bent cold and hammered until the two parts of the shank touch as shown in Fig. Q 4.1, without fracture.

On other samples the rivet heads are to be flattened, while hot, until the diameter is 2,5 times the diameter of the shank as shown in Fig. Q 4.2, without cracking at the edges.

Fig. Q 4.1

Fig. Q 4.2

Identification

429 Bars and manufactured rivets are to be identified in accordance with Q 109.

Documentation

430 The manufacturer is to supply the information and certificates detailed in Q 110.

Section 5

STEEL CASTINGS

Scope

501 (*a*) Important steel castings intended for use in boiler, pressure vessel and machinery construction are to be manufactured and tested in accordance with the requirements of this Section and the relevant parts of Q 1 and Q 2.

The requirements for castings intended for pressure containment or for general machinery construction are given in 501 to 510. Steel castings for crank shafts are to comply with the requirements given in 511 to 520. The requirements for steel propeller castings are given in 521 to 530. Reference should be made to Q 8 for the requirements relevant to cast iron crank shafts and to Q 9 for copper alloy propellers.

Where small and identical castings are produced in large quantities, the Surveyor may adopt an alternative system of quality control provided it is approved and the required standard of inspection is maintained by the manufacturer.

CASTINGS FOR PRESSURE CONTAINMENT AND GENERAL MACHINERY CONSTRUCTION

(*b*) The requirements in 502 to 510 are primarily intended for castings such as valve bodies and fittings for boilers and pressure vessels, where the design pressure is in excess of 10 kg/cm^2 (150 lb/in^2), turbine casings and associated castings. Castings for general machinery construction, excluding crank shafts and propellers, are also to be manufactured and tested to these requirements.

Provision is made for four categories of castings which differ mainly in respect of testing procedures and are intended for the following uses:—

Category I		Where design is based on guaranteed values for elevated temperature properties.
Category II	(a)	Where design is based on nominal values for elevated temperature properties, which are not required to be proved by test.
	(b)	Castings for general machinery construction.
Category III		For special low temperature service where the steel is to have guaranteed low temperature Charpy V-notch properties. In this case the proposed specification is to be submitted for approval.

Alternatively, steel castings complying with national or proprietary specifications may be accepted provided these specifications give reasonable equivalence to the requirements of this Section.

Manufacturer

502 All castings are to be made at foundries approved by the Committee.

Steel is to be manufactured in accordance with Q102 (a).

All flame cutting or scarfing to remove surplus metal is to be completed before final heat treatment of the casting and pre-heating is to be applied when necessary. Alloy steel castings are generally to be given a preliminary annealing heat treatment prior to flame cutting or scarfing. The affected areas are to be ground smooth.

Chemical Composition

503 For Categories I and II the chemical composition is to comply with the requirements given in Table Q 5.1.

Where it is proposed to use steels of higher carbon content or alloy steels not specified in Table Q 5.1, details of the chemical composition, heat treatment and mechanical properties are to be submitted for approval.

The chemical composition of castings for Category III is to comply with the approved specification.

Heat Treatment

504 (*a*) Steel castings are to be uniformly heated to a temperature above the upper critical point to refine the grain structure and are to be:—

(i) fully annealed by cooling slowly in the furnace in a uniform manner,

or (ii) normalised by cooling in air,

TABLE Q 5.1

Chemical Composition of Castings for Pressure Containment and General Machinery Construction

Grade of Steel	Tensile Strength		Chemical Composition of Ladle Samples—per cent									
	kg/mm²	ton/in²	C max.	Si	Mn	S max.	P max.	Ni max.	Cr	Mo	Cu max.	V
Carbon	41–52	26·0–33·0	0,20	0,15–0,60	0,50–1,00	0,050	0,050	0,40	0,25 max.	0,15 max.	0,30 (Note 1)	—
	44–55	27·9–34·9	0,25	0,15–0,60	0,60–1,20	0,050	0,050	0,40	0,25 max.	0,15 max.	0,30 (Note 1)	—
Carbon-Manganese	45–55	27·9–34·9	0,17	0,15–0,60	0,90–1,60	0,050	0,050	0,40	0,25 max.	0,15 max.	0,30 (Note 1)	—
½Mo	44–60	27·9–38·1	0,25	0,15–0,50	0,50–1,00	0,050	0,050	0,40	0,25 max.	0,40–0,70	0,30	—
1Cr–½Mo	47–70	29·8–44·5	0,23	0,15–0,60	0,50–0,80	0,050	0,050	0,40	1,00–1,50	0,45–0,65	0,30	—
2¼Cr–1Mo	47–70	29·8–44·5	0,20	0,15–0,60	0,40–0,70	0,050	0,050	0,40	2,00–2,75	0,90–1,20	0,30	—
½Cr–½Mo–¼V	52–70	33·0–44·5	0,18	0,15–0,50	0,40–0,80	0,050	0,050	0,40	0,25–0,50	0,50–0,70	0,30	0,22–0,30

NOTE 1. Total residual elements 0,80 per cent maximum.

or (iii) normalised by cooling in air followed by a tempering treatment. For carbon and carbon-manganese steel castings this tempering temperature is to be not less than 600°C.

or (iv) a combination of the above treatments consisting of annealing or homogenising at a relatively high temperature as a preliminary refining treatment to subsequent normalising and tempering.

(*b*) All alloy steel castings are to be heat treated as in (iv) above at temperatures suitable for the chemical composition and specified mechanical properties.

(*c*) Turbine casings and castings of structural importance, e.g. castings for engine bedplates, are to be heat treated by methods (i), (iii), or (iv) as above. After either full annealing as in (i), or tempering, as in (iii) or (iv), the castings are to be furnace cooled to a temperature of 200C° or less.

(*d*) When it is proposed to adopt other heat treatments full details are to be submitted for approval.

Test Material

505 (*a*) Test material is to be cast attached to each casting at positions agreed between the manufacturer and Surveyor. In all cases both the test material and the casting are to be identified by the Surveyor before separation.

When a number of castings, each less than 500 kg (1100 lb) in weight, are produced from one cast and they are heat treated together in one furnace then a system of batch testing may be adopted. The number of tests required and the method of providing the test material is to be agreed with the Surveyor.

(*b*) The test material is not to be detached from the casting it represents until all heat treatment has been completed.

(*c*) *Category I.* At least one tensile and bend test is to be made at ambient temperature for each casting. When large castings are made from more than one cast of steel or are of complex design, the number and location of test material is to be agreed with the Surveyor.

A tensile test at elevated temperature is to be made for each casting, in accordance with Q 205, except when:—

(i) the reference test temperature is 100°C or less,

(ii) the specified minimum value for the 0,2 per cent proof stress value at the reference test temperature is higher than the corresponding stress-to-rupture value.

(*d*) *Category II.* Test material is to be provided for the tests specified in 505(c), except that tensile tests at elevated temperatures are not required.

(*e*) *Category III.* Test material is to be provided for the tests specified in 505(*d*) and for one set of Charpy V-notch test pieces.

(*f*) The dimensions of the tensile and bend test pieces are to comply with Q 2. Test pieces for tensile tests at ambient temperature are to have a diameter of not less than 14 mm (0·564 in).

Impact test pieces are to be machined in accordance with Q 2.

Mechanical Properties

506 (*a*) *Category I.* The results of all tensile tests at ambient temperature and the lower yield or 0,2 per cent proof stress values at the reference test temperature given in the order are to comply with the values given in Table Q 5.2.

Bend test pieces are to withstand being bent through an angle of 120° round a former having a diameter not greater than that specified in Table Q 5.2.

(*b*) *Category II.* The results of tensile tests at ambient temperature are to comply with the values given in Table Q 5.2. For design purposes this Table also contains nominal values of yield or 0,2 per cent proof stress values at elevated temperatures for carbon and carbon-manganese steels.

Bend test pieces are to withstand being bent through an angle of 120° round a former having a diameter not greater than that specified in Table Q 5.2.

(*c*) *Category III.* The Charpy V-notch tests are to be made at or below the reference test temperature given in the order. The results of the tensile, bend and Charpy V-notch tests are to comply with the approved specification.

(*d*) If for any reason after testing as above, a casting is given a further full annealing or normalising and tempering heat treatment, e.g. after weld repairs, then the original tests are to be disregarded and further complete mechanical tests are to be made.

Inspection

507 (*a*) The manufacturer is expected to make any tests necessary to prove the casting technique for prototype castings.

When castings are produced in regular quantities the manufacturer is expected to make periodical examinations to verify the continued efficiency of the manufacturing technique and the Surveyor is to be given the opportunity to witness these tests.

TABLE Q 5.2

Mechanical Properties of Castings for Pressure Containment and General Machinery Construction

Grade of Steel	Yield Stress Minimum kg/mm^2	Tensile Strength kg/mm^2	Elongation on $5{,}65\sqrt{So}$ % Minimum	Reduction of Area % Minimum	Bend Test, Maximum dia. of Former	Minimum lower yield or 0,2 % proof stress, kg/mm^2						
						100°C	150°C	200°C	250°C	300°C	350°C	400°C
CATEGORY I												
Carbon	22,5	41–52	22	35	3t	18,3	17,6	17,0	15,9	14,2	13,4	12,9
Carbon	24,5	44–55	22	35	3t	20,4	18,9	18,6	17,3	16,0	15,0	14,0
Carbon-Manganese	24,5	44–55	22	35	3t	20,4	18,9	18,6	17,3	16,0	15,0	14,0
½Mo	24,0	44–60	18	30	3t	Values by agreement with the manufacturer						
1Cr–½Mo	26,0	47–70	17	30	3t							
2¼Cr–1Mo	26,0	47–70	17	30	6t							
½Cr–½Mo–¼V	29,0	52–70	17	30	6t							
CATEGORY II						Lower yield or 0,2% proof stress, kg/mm^2 (Note 1)						
Carbon	21,0	41–52	22	35	3t	16,9	16,2	15,9	14,6	12,9	11,9	11,5
Carbon	22,5	44–55	22	35	3t	18,3	17,3	17,0	15,6	14,2	13,2	12,9
Carbon-Manganese	22,5	44–55	22	35	3t	18,3	17,3	17,0	15,6	14,2	13,2	12,9

t = thickness of bend test piece.

NOTE 1. These values are included for design purposes and do not require to be proved by test.

or in British units:—

TABLE Q 5.2

Mechanical Properties of Castings for Pressure Containment and General Machinery Construction

Grade of Steel	Yield Stress Minimum ton/in²	Tensile Strength ton/in²	Elongation on $5{\cdot}65\sqrt{So}$ % Minimum	Reduction of Area % Minimum	Bend Test Maximum dia. of Former	Minimum lower yield or 0·2 % proof stress— ton/in² lb/in²						
						100°C	150°C	200°C	250°C	300°C	350°C	400°C
CATEGORY I												
Carbon	14·3	26·0–33·0	22	35	3t	11·6 26 000	11·2 25 000	10·8 24 200	10·1 22 600	9·0 20 200	8·5 19 100	8·2 18 300
Carbon	15·5	27·9–34·9	22	35	3t	12·9 29 000	12·0 26 900	11·8 26 500	11·0 24 600	10·2 22 800	9·5 21 300	8·9 19 900
Carbon-Manganese	15·5	27·9–34·9	22	35	3t							
½Mo	15·2	27·9–38·1	18	30	3t	Values by agreement with the manufacturer						
1Cr–½Mo	16·5	29·8–44·5	17	30	3t							
2¼Cr1–Mo	16·5	29·8–44·5	17	30	6t							
½Cr–½Mo–¼V	18·4	33·0–44·5	17	30	6t							
CATEGORY II						Lower yield or 0·2% proof stress, lb/in² (Note 1)						
Carbon	13·3	26·0–33·0	22	35	3t	24 000	23 000	22 600	20 800	18 300	16 900	16 400
Carbon	14·2	27·9–34·9	22	35	3t	26 000	24 600	24 200	22 200	20 200	18 800	18 300
Carbon-Manganese	14·2	27·9–34·9	22	35	3t							

t = thickness of bend test piece

NOTE 1. These values are included for design purposes and do not require to be proved by test.

(*b*) All castings are to be cleaned and adequately prepared for inspection. Suitable methods include pickling, caustic cleaning, wire brushing, local grinding, shot or sand blasting. Before examination, the surfaces must not be hammered, peened or treated in any way which may obscure defects.

Turbine casings are to be examined by magnetic particle method in, at least, all areas containing changes of section and where surplus metal has been removed by flame cutting. Where component castings are to be welded together to form a turbine casing, the material in way of the weld preparations in the component castings is to be examined by radiography. This examination is to be carried out prior to welding.

Castings of structural importance, which in service are subject to significant fatigue loading conditions, e.g. castings for engine bedplates, are also to be examined by magnetic particle methods.

In all cases supplementary examinations by radiography, ultrasonic or other approved methods of non-destructive testing in order to determine the soundness of the castings may also be requested. When such examination is to be carried out, it should be at positions, mutually agreed by the Surveyor and manufacturer, where experience shows that cavities, contraction cracks or other defects are most likely to occur.

(*c*) The Surveyor is to examine each large casting before final acceptance at the foundry.

Repair of Defects

508 (*a*) When defects are found in a casting these are to be removed by grinding or by chipping and grinding. Flame scarfing or arc-air gouging may also be used provided that pre-heating is employed when necessary and that the surfaces of the resulting depressions are subsequently ground smooth. Complete elimination of the defective material is to be proved by magnetic particle tests. Shallow grooves or depressions resulting from the removal of defects can, at the Surveyor's discretion, be accepted provided these are blended by grinding.

(*b*) Proposals to repair a defective casting by welding are to be submitted to the Surveyor before work is commenced. The Surveyor is to satisfy himself that the number and size of the defects are such that the casting can be efficiently repaired.

When it has been agreed that the casting can be repaired the procedure is to be in accordance with Q 108 and the area is to be prepared in a form suitable for welding. All castings in alloy steels and, if necessitated by the shape, castings in carbon or carbon-manganese steels are to be given a preliminary refining heat treatment prior to carrying out weld repairs. An electric arc welding process is to be used and the weld deposit is to have properties similar to and in no way inferior to the parent metal. Welding of the affected parts is to be undertaken by a procedure the essential elements of which have been tested previously by the manufacturers and approved by the Surveyor. The welding is to be done under cover in positions free from draughts and adverse weather conditions by competent welders with adequate supervision.

After welding, the castings are to be suitably heat treated either by annealing, normalising and tempering or stress relieving at a temperature of not less than 600° C. The type of heat treatment employed will be dependent on the size, position and nature of the defects. On completion of heat treatment, the weld repairs and adjacent metal are to be ground smooth and proved by a suitable method of magnetic particle inspection. Subject to the approval of the Surveyor, a local stress relieving heat treatment may be carried out where the area involved is small and machining of the casting has reached an advanced stage.

Identification

509 Castings are to be identified in accordance with Q 109.

Documentation

510 The manufacturer is to supply the information detailed in Q 110 and is to provide the Surveyor with a statement and/or sketch detailing the extent and location of the welded repairs made to each casting together with details of the heat treatment carried out at all stages.

CASTINGS FOR CRANKSHAFTS

Scope

511 Steel castings for crank shafts are to be manufactured and tested in accordance with 511 to 520 and the relevant parts of Q 1 and Q 2.

Alternatively, steel castings which comply with national or proprietary specifications may be accepted provided these specifications give reasonable equivalence to the requirements of this Section.

Manufacture

512 Castings are to be manufactured in accordance with 502.

The castings are to be produced by an approved method.

Chemical Composition

513 The chemical composition of ladle samples is to be within the following limits:—

Carbon	0,40% Max.	Copper	0,40% Max.
(*see* Note)		Nickel	0,40% Max.
Silicon	0,15–0,60%	Chromium	0,40% Max.
Manganese	0,60% Min.	Molybdenum	0,20% Max.
Sulphur	0,040% Max.	Total (Cu+Ni+Cr+Mo)	
Phosphorus	0,040% Max.		1,0% Max.

NOTE:—Weld repairs will not be permitted when the carbon content of the steel exceeds 0,30% or its carbon equivalent, given by

$$C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}, \text{ exceeds } 0{,}65\%$$

(*See* Chapter R(H) for further requirements).

Where it is proposed to use steel of higher carbon content or alloy steels, details of the chemical composition, heat treatment and mechanical properties are to be submitted for approval.

Heat Treatment

514 Castings are to be heat treated in accordance with methods (i), (iii) or (iv) of 504(*a*). After either full annealing, as in (i) or tempering, as in (iii) or (iv) the castings are to be furnace cooled to a temperature of 200°C or less.

Test Material

515 (*a*) The test material is to be provided as an integral part of each casting. At least one tensile and one bend test piece are required from each casting.

(*b*) Test pieces are to be prepared in accordance with Q 2. The diameter of the tensile test piece is to be not less than 14 mm (0·564 in) unless otherwise agreed.

Mechanical Properties

516 The tensile strength is to comply with the range specified in the order which is not to exceed 11 kg/mm² (7·0 ton/in²) within the general limits of 44 and 65 kg/mm² (27·9 and 41·3 ton/in²).

The yield stress is to be not less than half the actual tensile strength.

The elongation and reduction of area values are to comply with the values given in Table Q 5.3 appropriate to the actual tensile strength.

Bend test pieces are to withstand being bent through an angle of 180° round a former having a diameter not greater than two times the thickness of the test piece. Where the actual tensile strength of the steel is in excess of 55 kg/mm² (34·9 ton/in²) the diameter of the former may be increased to three times the thickness of the test piece.

Inspection

517 (*a*) The manufacturer is to make any tests necessary to prove the casting technique for prototype castings.

The Surveyor is to examine each casting before final acceptance at the foundry.

(*b*) Crank web and combined web and pin castings are to be examined by magnetic particle methods on all surfaces. For this purpose "as cast" surfaces are to be cleaned and prepared for inspection. Suitable methods include pickling, caustic cleaning, wire brushing, local grinding, shot or sand blasting. Before examination, the surfaces must not be hammered, peened or treated in any way which may obscure defects.

Any irregularities on surfaces which may interfere with the detection of defects should be smoothed by local grinding. It is recommended that a preliminary examination should be carried out before final heat treatment but all machined surfaces are to be examined in the finished condition by suitable magnetic particle methods.

Manufacturers are to carry out an ultrasonic test on each casting and are to provide the Surveyor with a signed statement that such inspection has not revealed any significant internal defects.

TABLE Q 5.3

Mechanical Properties of Castings for Crankshafts

Actual Tensile Strength		Elongation on $5{,}65\sqrt{So}$ % minimum	Reduction of area % minimum
kg/mm²	ton/in²		
Over 44 to 50	Over 27·9 to 31·8	24	40
,, 50 to 55	,, 31·8 to 34·9	22	35
,, 55 to 60	,, 34·9 to 38·1	19	30
,, 60 to 65	,, 38·1 to 41·3	17	30

Repair of Defects

518 (*a*) When defects are found in a casting these are to be removed by grinding or by chipping and grinding. Flame scarfing or arc-air gouging may also be used provided that preheating is employed when necessary and that the surfaces of the resulting depressions are subsequently ground smooth. Complete elimination of the defective material is to be proved by magnetic particle tests. Shallow grooves or depressions resulting from the removal of defects can, at the Surveyor's discretion, be accepted provided these are blended by grinding.

(*b*) The acceptance of repair by welding is subject to special consideration and any action is to be in accordance with the provisional Rules for repairs by welding to steel castings for crank shafts contained in Chapter R(H).

Identification

519 Castings are to be identified in accordance with Q 109.

Documentation

520 The manufacturer is to supply the information detailed in Q 110. In addition the Surveyor is to be provided with:—

(i) a statement and/or sketch detailing the extent and location of all welded repairs made to each casting together with details of the heat treatment carried out at all stages.

(ii) a certificate of ultrasonic examination as required by 517(*b*).

CASTINGS FOR PROPELLERS

Scope

521 Steel castings for propellers may be made in carbon, low alloy or stainless steel and are to be manufactured and tested in accordance with 521 to 530 and the relevant parts of Q 1 and Q 2. These only give outline requirements and details of the proposed chemical composition, heat treatment and mechanical properties are to be submitted for approval.

In this Section the term "severe ice service" is intended to indicate use in ice breakers or ships with Class I* or Class I Ice Strengthening.

Manufacture

522 Castings are to be manufactured in accordance with 502. Ferritic steel for propellers intended for severe ice service is to be made by a fine grain practice.

Chemical Composition

523 The chemical composition is to comply with the approved specification.

Heat Treatment

524 Castings are to be heat treated in accordance with 504(*a*) and with the approved specification.

Test Material

525 (*a*) Test material is to be provided integral with the hub of propeller castings and with the flange or propeller blade castings.

At least one tensile and one bend test piece are to be taken from each casting. In addition, a set of Charpy V-notch test pieces is to be taken from all carbon or low alloy steel castings intended for severe ice service and from all ferritic or martensitic type stainless steel castings. Impact tests are not required from carbon or low alloy steel castings intended for general service or from austenitic stainless steel castings regardless of service.

(*b*) All test pieces are to be prepared in accordance with Q 2. The diameter of the tensile test piece is to be not less than 14 mm (0·564 in) unless otherwise agreed.

Mechanical Properties

526 (*a*) The results of all tensile and bend tests are to comply with the approved specification.

(*b*) The Charpy V-notch tests are to be made at or below the following temperatures:—

Carbon, low alloy, ferritic or martensitic type stainless steel propellers intended for severe ice service:—test temperature −10°C.

Ferritic or martensitic type stainless steel propellers intended for general service:—test temperature 0°C.

The average value for the Charpy V-notch tests is to be not less than 2,1 kg m (15 ft lb). When the average result fails to meet this value, retests in accordance with Q 106(*b*) may be carried out, irrespective of the actual average value obtained.

The results of the retests are to be added to the original values and the average is to be not less than 2,1 kg m (15 ft lb). For martensitic 13 per cent chromium steel propeller castings, special consideration will be given to acceptance if the average value obtained is not less than 1,4 kg m (10 ft lb).

Inspection

527 The Surveyor is to examine each casting before final acceptance at the foundry. The surfaces of the blade roots are to be examined by magnetic particle methods or in the case of austenitic stainless steel by dye penetrant methods.

Repair of Defects

528 The removal of minor surface defects by grinding and weld repairs are to be carried out in accordance with the requirements of 508.

Identification

529 Castings are to be identified in accordance with Q 109.

Documentation

530 The manufacturer is to supply the information detailed in Q 110 and is to provide the Surveyor with a statement and/or sketch detailing the extent and location of the repairs of welding made to each casting together with details of the heat treatment carried out at all stages.

Section 6

STEEL FORGINGS

Scope

601 Important steel forgings intended for use in boilers, pressure vessels and machinery construction are to be manufactured and tested in accordance with the requirements of this Section and the relevant parts of Q 1 and Q 2.

In this Section the term "severe ice service" is intended to indicate use in ice breakers or for ships with Class I* or Class I Ice Strengthening.

Requirements for general forgings including screw shafts for severe ice service are given in 601 to 610. Requirements for the following particular forgings are given in the sub-sections indicated:—

	Paragraphs
Crank shaft forgings	611 to 620
Gear forgings	621 to 630
Turbine forgings	631 to 640
Forgings for boilers and pressure vessels	641 to 650

The requirements for shafts machined from hot rolled bars are given in Q 4.

Where small and identical forgings are produced in large quantities, the Surveyor may adopt an alternative system of quality control provided it is approved and the required standard of inspection is maintained by the manufacturer.

GENERAL FORGINGS

Manufacture

602 (*a*) The forgings are to be manufactured from killed steel. Screw shafts intended for severe ice service and other forgings for low temperature service are to be made from grain controlled steel.

(*b*) When forgings are made from ingots, or from blooms forged from ingots, the ingots are to be cast in metal moulds with the larger cross-section uppermost and with efficient feeder heads. The forgings are to be gradually and uniformly hot worked and are to be brought as nearly as possible to the finished shape and size. Where practicable they are to be worked so as to cause metal flow in the most favourable direction having regard to the mode of stressing in service. Adequate top and bottom discards are to be made to ensure freedom from piping and harmful segregations in the finished forgings.

Unless otherwise approved the maximum sectional area of any part of a forging (as forged) is not to exceed:—

$\frac{1}{3}$A where the length of any section is greater than its diameter,

$\frac{2}{3}$A where the length of any section is less than its diameter (e.g. a collar),

A is the average sectional area of the ingot or of the ingot after upsetting if such an operation is involved.

(*c*) When forgings are made from rolled products the maximum sectional area of a forging (as forged) is not to exceed:—

(i) when made from products rolled from ingots cast large end uppermost with efficient feeder heads,

$\frac{1}{4}$A where the length of any section is greater than its diameter,

or $\frac{1}{2}$A where the length of any section is less than its diameter (e.g. a collar),

or (ii) when made from products rolled from other types of ingots,

$\frac{1}{6}$A where the length of any section is greater than its diameter,

or $\frac{1}{3}$A where the length of any section is less than its diameter (e.g. a collar),

A is the average cross-sectional area of the original ingot.

(*d*) Disc or ring type forgings are to be made from pieces which have been hot cut or machined from a billet, bloom or ingot. The thickness of any part of a disc (as forged or as stamped) is to be not more than:—

one half of the original length of the piece when this has been cut from a billet or bloom,

or

one third of the original length of the piece when this has been cut from an ingot.

(*e*) The shaping of forgings or thick slabs by flame cutting is to be undertaken in accordance with a procedure approved by the Surveyor. Where possible, flame cutting is to be carried out before the heat treatment operation of 604.

Pre-heating is to be employed when necessitated by the thickness and/or composition of the steel.

For machinery parts that are subjected to significant fatigue stresses during service, a depth of at least 7,5 mm (0·3 in) is to be removed by machining from all flame cut surfaces. If required by the Surveyor, selected areas of such machined surfaces are to be prepared and then examined by magnetic crack detection or other equivalent method to his satisfaction.

Chemical Composition

603 (*a*) For forgings in carbon and carbon-manganese steels and which are not intended for welding, the chemical composition of the ladle sample is to comply with the following:—

Carbon	0,50% max.
Silicon	0,10% to 0,45%
Manganese	0,30% to 1,5%
Sulphur	0,050% max.
Phosphorus	0,05% max.

When it is proposed to use a steel of higher carbon content, or an alloy steel, details of the proposed composition, heat treatment and properties are to accompany the plans which are submitted for approval by the builder.

(*b*) Forgings to which structural items are to be attached by welding or which are intended for parts of a fabricated component are to be of weldable quality with a carbon content generally not exceeding 0,23 per cent. Where the carbon content exceeds 0,23 per cent, details of the chemical composition, heat treatment and mechanical properties are to be submitted for approval.

Heat Treatment

604 All forgings are to be fully heat treated before being put into service. Procedures must be such as to ensure that if full treatment is not carried out by the forgemaster adequate provision with regard to test material is to be made for any treatment to be carried out at a later stage.

Forgings are to be heated to a uniform temperature above the upper critical point to refine the grain and are to be:—

(i) Fully annealed by cooling slowly in the furnace in a uniform manner,

or (ii) normalised by cooling in air followed by a tempering treatment to relieve internal stresses if the diameter of the body of the forging is equal to or greater than the values given in Table Q 6.1. Smaller diameter forgings may also be tempered after the normalising heat treatment at the option of the forgemaster,

or (iii) hardened by quenching in oil followed by tempering. Unless otherwise agreed, all large forgings are to be rough machined prior to the hardening heat treatment.

Where it is proposed to use other methods for hardening, full details are to be submitted for approval.

TABLE Q 6.1

Dimensions of Forgings to be Tempered after Normalising

% Carbon Content of Steel		Equivalent Diameter of Body of Forging
Over	Up to and including	
0,40	0,50	400 mm (16 in)
0,35	0,40	500 mm (20 in)
0,30	0,35	700 mm (28 in)
0,25	0,30	900 mm (35 in)
	0,25	1000 mm (39 in)

Test Material

605 (*a*) Test material is to be provided integral with the forging and with a cross-sectional area of not less than that of the main part of the forging. At least one tensile and one bend test are to be taken from each forging, except where both the weight and length are in excess of 4000 kg (4 tons) and 3 m (10 ft) respectively when tensile and bend tests are to be taken from each end. These limits refer to the "as forged" weight and length but excluding the test material.

(*b*) When a forging is subsequently divided into a number of items all of which are heat treated together in the same furnace then for test purposes this may be considered as one forging and the test material required is to be related to the total length and weight of the original forging.

Where a number of separate forgings are made from one cast of steel and are heat treated together in one furnace then a system of batch testing may be adopted. The number of tests required and the method of providing the test material is to be agreed with the Surveyor.

(*c*) Tensile and bend test pieces are to be cut longitudinally or parallel to the direction of principal grain flow. Where test pieces cannot reasonably be provided in the longitudinal direction they may be cut in a transverse direction.

(*d*) The dimensions of the tensile test pieces are to comply with Q 2 and they are to have a diameter of not less than 14 mm (0·564 in) except where the dimensions of the forging will not permit this diameter of test piece being prepared. In such cases the test piece is to be of the largest practicable diameter.

Bend test pieces are to be machined in accordance with Q 2, the subsidiary test piece (20 mm by 10 mm) being used when the specified minimum tensile strength is in excess of 55 kg/mm² (34·9 ton/in²).

(*e*) For screw shafts intended for severe ice service, in addition to the tensile and bend tests, Charpy V-notch tests are to be taken from the test material at the propeller end of each shaft. The test pieces are to be cut in a longitudinal direction and the dimensions are to be in accordance with Q 2.

Mechanical Properties

606 (*a*) The tensile strength of steel forgings is to comply with the range specified in the order. With the exception of screw shafts and propeller nuts the specified range for carbon and carbon-manganese steel forgings is not to exceed 10 kg/mm² (6·3 ton/in²) within the general limits of 44 and 70 kg/mm² (27·9 and 44·5 ton/in²).

When it is proposed to use a carbon or carbon-manganese steel of higher tensile strength full details are to be submitted for approval.

(*b*) Screw shafts are, in general, to be restricted to a range of tensile strength between 44 and 52 kg/mm² (27·9 and 33 ton/in²).

(*c*) Material for propeller nuts may be within the limits of 35 and 41 kg/mm² (22·2 to 26 ton/in²).

(*d*) The percentage elongation is not to be less than the value given in Table Q 6.2 appropriate to the actual tensile strength of the steel.

Bend test pieces are to withstand being bent without fracture through an angle of 180° round a former having a diameter not greater than that specified in Table Q 6.3.

Charpy V-notch tests from screw shafts intended for severe ice service are to be carried out at −10°C and are to give an average energy value of not less than 2,1 kg m (15 ft lb).

TABLE Q 6.2

Tensile Properties of Carbon Steel Forgings

Actual Tensile Strength		Elongation on $5{,}65\sqrt{So}$ % minimum	
kg/mm²	ton/in²	Longitudinal or in the Direction of Principal Grain Flow	Transverse or Across the Direction of Principal Grain Flow
35 to 40	22·2 to 25·4	27	22
Over 40 to 45	Over 25·4 to 28·6	25	21
„ 45 to 50	„ 28·6 to 31·8	23	19
„ 50 to 55	„ 31·8 to 34·9	22	18
„ 55 to 60	„ 34·9 to 38·1	20	16
„ 60 to 65	„ 38·1 to 41·3	18	14
„ 65 to 70	„ 41·3 to 44·5	16	12

TABLE Q 6.3

Bend Tests for Carbon Steel Forgings

Actual Tensile Strength		Maximum Internal Diameter of Bend or Diameter of Former	
kg/mm²	ton/in²	Longitudinal or in the Direction of Principal Grain Flow	Transverse or Across the Direction of Principal Grain Flow
Up to 50	Up to 31·8	$\frac{2}{3}$t	$1\frac{1}{3}$t
Over 50 to 60	Over 31·8 to 38·1	t	2t
„ 60 to 70	„ 38·1 to 44·5	2t	4t
		Where t=thickness of test piece	

Inspection

607 (*a*) The Surveyor is to examine each forging before final acceptance at the forge.

(*b*) Unless otherwise agreed, the forgemaster is to carry out an ultrasonic test on all forgings for shafts and other parts subject to significant fatigue loading, where the diameter or equivalent ruling section is 250 mm (10 in) or greater and is to provide the Surveyor with a signed statement that such inspection has not revealed any significant internal defects.

(*c*) When small forgings are tested as a batch, the hardness of each forging is to be determined including those from which material is to be cut for the provision of tensile and bend test pieces. The hardnesses of the forgings are to comply with a specification approved by the Surveyor before manufacture of the forgings. The Surveyor is to satisfy himself that the inspection procedure for surface condition and soundness adopted by the manufacturer is adequate.

Repair of Defects

608 The repair of defects by welding is not permitted.

Identification

609 Forgings are to be identified in accordance with Q 109.

Documentation

610 The manufacturer is to supply the information detailed in Q 110 and a certificate of ultrasonic examination as required by 607(*b*).

CRANK SHAFT FORGINGS

Scope

611 Solid forged crank shafts and forgings for use in the construction of built or semi-built crank shafts are to be manufactured and tested in accordance with the requirements of this Section and the relevant parts of Q 1 and Q 2.

Manufacture

612 Forgings are to be manufactured in accordance with the requirements of 602.

For combined web and pin forgings the proposed method of forging is to be submitted for approval. It is recommended that these forgings be made by a folding method. Other methods which can be shown to produce sound forgings with satisfactory mechanical properties will be considered but where the gapping method is used for cranks having a pin diameter exceeding 510 mm (20 in) this will only be accepted provided that an upsetting operation is included in the manufacturing sequence. In general, the amount of work during the upsetting operation is to be such that the reduction in the original length of the ingot (after discard) or bloom is not less than 50 per cent.

Chemical Composition

613 The chemical composition is to be within the limits specified in 603 unless otherwise agreed.

Heat Treatment

614 Forgings are to be heat treated in accordance with the requirements of 604.

Test Material

615 Test material is to be provided on each forging as specified in 605. On slabs for crankwebs the test pieces are to be taken transversely.

Mechanical Properties

616 (*a*) The tensile strength is to comply with the range specified in the order. The specified range for carbon and carbon-manganese steel forgings is not to exceed 10 kg/mm² (6·3 ton/in²) within the general limits of 44 and 70 kg/mm² (27·9 and 44·5 ton/in²).

(*b*) For crank webs and other parts where minimum yield stresses are specified the yield stress is not to be less than 50 per cent of the minimum specified tensile strength. (*See* H 206).

(*c*) When it is proposed to use a steel of higher tensile strength full details, including yield stress, are to be submitted for approval.

(*d*) The percentage elongation is not to be less than the value given in Table Q 6.2 appropriate to the actual tensile strength of the steel.

Bend test pieces are to withstand being bent through an angle of 180° round a former having a diameter not greater than that specified in Table Q 6.3.

Inspection

617 (*a*) The Surveyor is to examine each forging before final acceptance at the forge.

(*b*) The forgemaster is to carry out an ultrasonic test on all forgings for crank shafts which have finished pins or journals in excess of 250 mm (10 in) diameter and is to provide the Surveyor with a signed statement that such inspection has not revealed any significant internal defects.

(*c*) Magnetic particle examination is to be carried out on the pins and journals of all solid forged crank shafts and on the pin fillet of all combined web and pin forgings. This examination is to be carried out in the finished machined condition. Where forgings are supplied in the black or rough machined condition, this examination is to be carried out by the engine builder.

(*d*) When small forgings are tested as a batch, hardness tests, as detailed in 607(c), are to be carried out.

Repair of Defects

618 The repair of defects by welding is not permitted.

Identification

619 Forgings are to be identified in accordance with Q 109.

Documentation

620 The manufacturer is to supply the information detailed in Q 110 and a certificate of ultrasonic examination as required by 617(b).

FORGINGS FOR REDUCTION GEARING

Scope

621 Forgings for pinions, pinion sleeves, gear wheels and gear wheel rims intended for reduction gearing where the transmitted power exceeds 150 shp are to be manufactured and tested in accordance with the requirements of this section and the relevant parts of Q 1 and Q 2. Where the transmitted power is less than 150 shp the manufacturer's certificate of test may be accepted.

Forgings for flexible couplings, quill shafts and gear wheel shafts are to comply with 601 to 610.

Specifications for materials of pinions, pinion sleeves, wheel rims, gear wheels, flexible couplings and quill shafts giving chemical analysis, heat treatment and mechanical properties are to be submitted for approval with the plans of gearing, as required by G 104 and H 302.

When the teeth of a pinion or gear wheel are to be surface hardened, i.e. case hardened, nitrided or induction hardened, the proposed specification together with details of the process and practice are to be submitted for approval. In general, for nitrided gears the treatment time should not be less than 60 hours. Unless otherwise agreed the specified minimum tensile strength of the core is to be 80 kg/mm² (50·8 ton/in²) for induction hardened or nitrided gearing and 75 kg/mm² (47·6 ton/in²) for case hardened gearing (*see* H 307). For purposes of initial approval the gear manufacturer is required to demonstrate by test that the surface hardening of the teeth is uniform and of the required depth and that it does not impair the soundness and quality of the steel.

Manufacture

622 (*a*) Forgings are to be manufactured in accordance with the requirements of 602.

Sleeve forgings are to be hollow forged or hollow rolled where practicable.

Rim forgings are to be expanded by forging or rolling where practicable.

(*b*) All forgings are to be made with sufficient material to permit an adequate machining allowance on all surfaces for the removal of unsound or decarburised material. For alloy steel forgings the machining allowance on surfaces where teeth will be cut is to be not less than the following:—

Finished diameter of toothed portion	*Machining Allowance*
200 mm (8 in) or less	15 mm (0·6 in) on diameter
Over 200 mm (8 in)	25 mm (1·0 in) on diameter

Chemical Composition

623 Gear wheel and rim forgings with a specified minimum tensile strength not in excess of 75 kg/mm² (47·6 ton/in²) may be made in carbon or carbon-manganese steel complying with the following limits:—

Carbon	0,60% max.
Silicon	0,10% to 0,45%
Manganese	0,30% to 1,50%
Sulphur	0,040% max.
Phosphorus	0,040% max.

Gear wheel or rim forgings where the specified minimum tensile strength is in excess of 75 kg/mm² (47·6 ton/in²) and all pinion or pinion sleeve forgings are to be made in a suitable alloy steel. Any of the following types of steel will be accepted:—

3% Ni
3½% Ni
1¾% Ni Cr Mo
2½% Ni Cr Mo
3% Ni Cr Mo
4¼% Ni Cr Mo
1% Cr Mo
3% Cr Mo

Where it is proposed to use other steels the proposed chemical composition is to be submitted for approval.

Heat Treatment

624 (*a*) Forgings may be either normalised and tempered, oil hardened and tempered or water hardened and tempered in accordance with the approved specification. The tempering temperature is not to be less than 550°C.

At the discretion of the manufacturer, heat treatment may be carried out either in the black "as forged" condition or after rough machining. It is recommended, however, that where the finished diameter of the toothed portion

exceeds 200 mm (8 in), forgings should be rough machined prior to hardening and tempering.

Where forgings are machined prior to heat treatment, the allowance left for final machining is to be sufficient to remove the decarburised surface material taking into account any bending or distortion which may occur.

(*b*) Where induction hardening or nitriding is to be carried out after machining of the gear teeth the forgings are to be heat treated at an appropriate stage to a condition suitable for the subsequent surface hardening.

(*c*) Forgings for gears which are to be case hardened after final machining are to be supplied in a condition suitable for subsequent machining and case hardening.

Test Material

Through hardened, induction hardened or nitrided gear forgings.

625 (*a*) At least one tensile and one bend test piece are to be taken from each forging in carbon or carbon-manganese steel and at least one tensile and one set of impact tests when the forgings are to be made in alloy steel. Sufficient test material is to be provided for this purpose and the test pieces are to be taken as follows:—

(i) Where the finished diameter over the portion where teeth will be cut is 200 mm (8 in) or less, the test pieces are to be cut in a longitudinal direction from the end of the forging (*see* Fig. Q 6.1).

(ii) Where the above finished diameter exceeds 200 mm (8 in) the test pieces are to be cut in a transverse or circumferential direction adjacent to the position where the teeth will be cut (*see* Fig. Q 6.2). In the case of forgings where the diameter of the journal precludes the preparation of test pieces from this position, test material may be provided on the ends of the journals. Where the finished journal diameter is 200 mm (8 in) or less these test pieces are to be cut in a longitudinal direction. Where the finished journal diameter exceeds 200 mm (8 in) the test pieces are to be cut in a transverse direction (*see* Fig. Q 6.3).

(iii) When the finished length of a pinion forging, excluding the journals, exceeds 1,25 m (4 ft) tests as prescribed in (ii) are required from each end.

(iv) When the finished diameter of a gear wheel or rim exceeds 2,5 m (8 ft) or the weight (as forged) exceeds 3000 kg (3 tons), two sets of tests are to be taken from positions diametrically opposed and for gear rim forgings from opposite ends when the width of the face on which teeth will be cut exceeds 1000 mm (39·4 in) (*see* Fig. Q 6.4).

(*b*) When a forging is subsequently divided into a number of items all of which are heat treated together in the same furnace then for test purposes this may be considered as one forging and the test material required is to be related to the total length and weight of the original forging.

Where a number of separate forgings are made from one cast of steel and heat treated together in one furnace then a system of batch testing may be adopted. The number of tests required and the method of providing the test material is to be agreed with the Surveyor.

(*c*) The dimensions of the tensile test pieces are to comply with Q 2 and they are to have a diameter of not less than 14 mm (0·564 in) except where the dimensions of the forging will not permit this diameter of test piece being prepared. In such cases the test piece is to be of the largest practicable diameter.

Bend test pieces are to be machined in accordance with Q 2 the subsidiary test piece (20 mm by 10 mm) being used when the specified minimum tensile strength is in excess of 55 kg/mm^2 (34·9 ton/in^2).

Impact test pieces are to be machined in accordance with Q 2 and may be of either the Izod, Charpy V-notch or Charpy U-notch types.

Case hardened gear forgings

(*d*) Sufficient material for test purposes both at the forgemaster's and manufacturer's works is to be provided generally as specified in (*a*) and (*b*) except that, irrespective of the dimensions or weight of the forging, tests are required from one position only and in the case of forgings with integral journals are to be cut in a longitudinal direction.

A sufficient number of test blocks with a cross-section of 63 mm (2·5 in) diameter and of suitable length are to be machined from the test material for use at the forge and gear manufacturer's works.

For small forgings where a system of batch testing is adopted, the test blocks may be machined from test material made from surplus steel from the same cast provided that the forging reduction approximates to that of the actual gear forgings.

Tensile and impact tests are to be taken by the forgemaster from test blocks which have been given a blank carburising and heat treatment cycle simulating that which will be subsequently applied to the forgings. These test pieces are to be prepared in accordance with (*c*) and are to be cut with their axis at about 12,5 mm (0·5 in) from the surface of the test block.

A similar set of mechanical tests are also to be taken at the gear manufacturer's works from test blocks which have been blank carburised and heat treated with the gear forgings they represent.

At the discretion of the manufacturer test blocks of larger cross-section may be blank carburised but these are then to be machined to 63 mm (2·5 in) diameter prior to the final hardening and tempering heat treatment.

Where it is proposed to adopt alternatives to the foregoing full details are to be submitted for consideration.

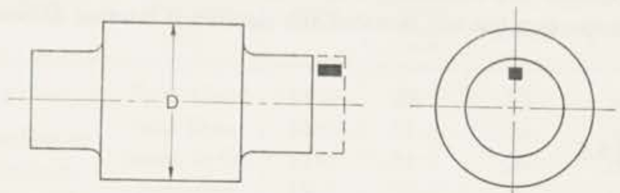


Fig. Q 6.1

Diameter D 200 mm (8 in) or less

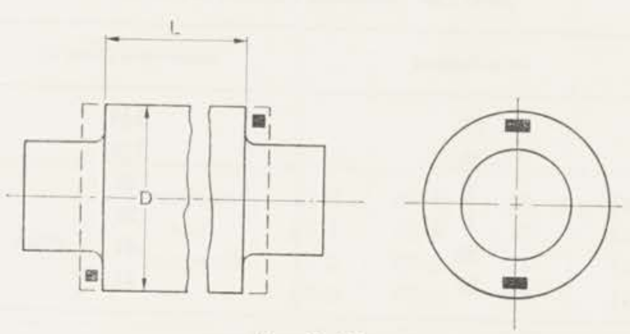


Fig. Q 6.2

Diameter D greater than 200 mm (8 in). Two sets of test pieces are required only when length L is greater than 1,25 m (4 ft).

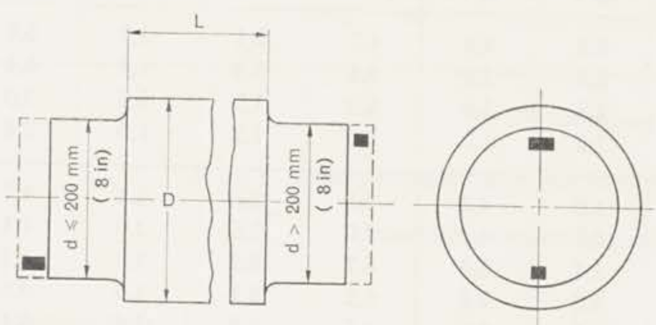


Fig. Q 6.3

Diameter D greater than 200 mm (8 in) but journal diameter precludes tests as shown in Fig. Q 6.2. When journal diameter d is 200 mm (8 in) or less, tests to be cut in longitudinal direction. When journal diameter d is greater than 200 mm (8 in) tests to be cut in transverse direction. Two sets of test pieces are required only when length L is greater than 1,25 m (4 ft).

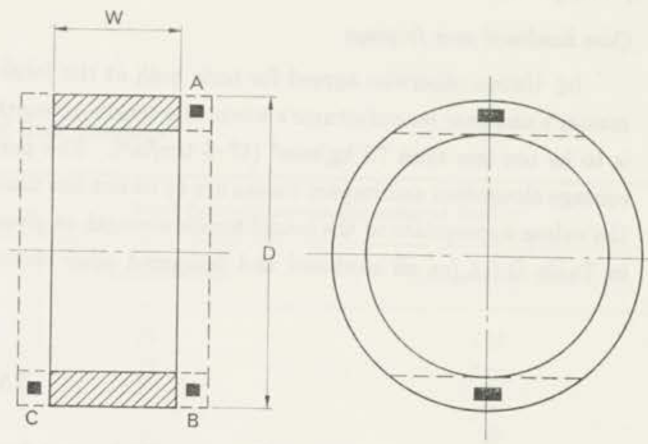


Fig. Q 6.4

Two sets of test pieces are required only when the diameter D is greater than 2,5 m (8 ft) or weight greater than 3000 kg (3 tons).

When the width W is 1000 mm (39·4 in) or less tests may be taken from positions A and B. When W exceeds 1000 mm (39·4 in) tests are to be taken from positions A and C.

Mechanical Properties

Through hardened gear forgings

626 (*a*) The tensile strength is to be within the range specified in the order. The specified range is not to exceed 10 kg/mm² (6·3 ton/in²). These ranges are to be within the general limits of 60 and 120 kg/mm² (38·1 and 76·2 ton/in²) for pinions or 45 and 100 kg/mm² (28·6 and 63·5 ton/in²) for gear wheels. Consideration is also to be given to maintaining the necessary hardness differential between pinion and gear wheel teeth (*see* H 303).

The percentage elongation is not to be less than the value given in Table Q 6.4 appropriate to the specified minimum tensile strength of the steel.

Bend test pieces from carbon and carbon-manganese steel forgings are to withstand being bent through 180° round a former having a diameter not greater than that specified in Table Q 6.4.

The impact tests from alloy steel forgings are to be made at room temperature and are to give energy values not less than the appropriate value given in Table Q 6.4.

Proposals to use materials of higher tensile strength are to be submitted for approval.

Induction hardened and nitrided gear forgings

(*b*) The tensile strength is to be not less than 80 kg/mm² (50·8 ton/in²) and the percentage elongation and impact values are to be not less than those given in Table Q 6.4 for alloy steel with the above specified minimum tensile strength.

Case hardened gear forgings

(*c*) Unless otherwise agreed for tests both at the forgemaster's and gear manufacturer's works the tensile strength is to be not less than 75 kg/mm² (47·6 ton/in²). The percentage elongation and impact values are to be not less than the values appropriate to the actual tensile strength as given in Table Q 6.4 for oil hardened and tempered alloy steels.

Inspection

627 (*a*) The Surveyor is to examine each forging before acceptance at the forge.

(*b*) The forgemaster is to carry out an ultrasonic examination of all forgings where the finished diameter of the toothed portion is in excess of 200 mm (8 in) and is to provide the Surveyor with a signed statement that such inspection has not revealed any significant internal defects.

TABLE Q 6.4

Mechanical Properties of Gear Forgings

Steel	Heat Treatment	Minimum Yield Stress kg/mm²	Specified Minimum Tensile Strength kg/mm²	Minimum Elongation % on $5{,}65\sqrt{So}$ Longl.	Minimum Elongation % on $5{,}65\sqrt{So}$ Transv. (Note 1)	Bend Test—Maximum Diameter of Former: Longitudinal	Bend Test—Maximum Diameter of Former: Transverse (Note 1)						
	Normalised	23	45	23	19	$\frac{2}{3}$t	$1\frac{1}{3}$t						
Carbon or	and Tem-	25	50	22	18	$\frac{2}{3}$t	$1\frac{1}{3}$t						
Carbon-	pered or Oil	28	55	20	16	t	2t						
Manganese	hardened	30	60	18	14	t	2t						
	and	33	65	17	12	2t	4t						
	Tempered	35	70	16	11	2t	4t						
								Minimum Impact Energy					
								Longitudinal			Transverse (Note 1)		
								Izod kg m	Charpy V-notch kg m	Charpy U-notch kg m/cm²	Izod kg m	Charpy V-notch kg m	Charpy U-notch kg m/cm²
	Normalised	33	60	18	14			2,8	2,2	4,7	2,1	1,7	3,8
Alloy	and	38	70	17	13			2,5	2,0	4,4	1,8	1,4	3,4
	Tempered	43	80	15	12			2,2	1,8	4,0	1,5	1,2	3,0
		48	90	13	11			1,9	1,5	3,6	1,2	1,0	2,6
		42	60	18	14			4,9	4,2	7,1	2,8	2,2	4,7
	Oil	47	70	17	13			4,7	4,1	7,0	2,5	2,0	4,4
Alloy	hardened	60	80	15	12			4,4	3,8	6,7	2,3	1,9	4,2
	and	70	90	13	10			4,0	3,4	6,2	2,1	1,6	3,8
	Tempered	80	100	12	8			3,6	3,0	5,7	1,8	1,4	3,4
		90	110	11	7			3,0	2,5	5,1	1,5	1,2	3,0

t = thickness of the test piece

NOTE 1. Circumferential test pieces from rim forgings are to give longitudinal properties.

Intermediate values may be obtained by interpolation.

or in British units:—

TABLE Q 6.4

Mechanical Properties of Gear Forgings

Steel	Heat Treatment	Minimum Yield Stress ton/in^2	Specified Minimum Tensile Strength ton/in^2	Minimum Elongation % on $5 \cdot 65\sqrt{So}$		Bend Test—Maximum Diameter of Former					
				Longl.	Transv. (Note 1)	Longitudinal			Transverse (Note 1)		
Carbon or Carbon-Manganese	Normalised and Tempered or Oil hardened and Tempered	14·6	28·6	23	19	$\frac{2}{3}$t			$1\frac{1}{3}$t		
		15·9	31·8	22	18	$\frac{2}{3}$t			$1\frac{1}{3}$t		
		17·8	34·9	20	16	t			2t		
		19·1	38·1	18	14	t			2t		
		21·0	41·2	17	12	2t			4t		
		22·0	44·4	16	11	2t			4t		
						Minimum Impact Energy					
						Longitudinal			Transverse (Note 1)		
						Izod ft lb	Charpy V-notch ft lb	Charpy U-notch ft lb	Izod ft lb	Charpy V-notch ft lb	Charpy U-notch ft lb
Alloy	Normalised and Tempered	21·0	38·1	18	14	20	16	17	15	12	14
		24·1	44·4	17	13	18	15	16	13	10	12
		27·3	50·8	15	12	16	13	14	11	9	11
		30·5	57·2	13	11	14	11	13	9	7	9
Alloy	Oil hardened and Tempered	26·7	38·1	18	14	35	31	26	20	16	17
		29·8	44·4	17	13	34	30	25	18	15	16
		38·1	50·8	15	12	32	28	24	17	14	15
		44·4	57·2	13	10	29	25	22	15	12	14
		50·8	63·5	12	8	26	22	21	13	10	12
		57·2	69·9	11	7	22	18	18	11	9	11

t = thickness of the test piece

NOTE 1. Circumferential test pieces from rim forgings are to give longitudinal properties.

Intermediate values may be obtained by interpolation.

Hardness Tests

(c) Hardness tests are to be carried out on all forgings after completion of heat treatment and prior to machining the gear teeth, except on forgings intended for case hardening.

When the diameter of the finished item is less than 500 mm (19·7 in) one hardness test is to be made on each forging.

When the diameter of the finished item exceeds 500 mm (19·7 in) at least two hardness tests are to be made on each forging at positions diametrically opposite on the portion where the teeth will be cut. When the length of this portion exceeds 500 mm (19·7 in) two tests are to be made at each end.

When the diameter of the finished item is 1000 mm (39·4 in) or more at least four hardness tests are to be made. These tests are to be spaced at equal distances round the circumference and this distance is not to exceed 1000 mm

(39·4 in). When the width of the face on which the teeth will be cut exceeds 500 mm (19·7 in) tests are to be made at each end.

(*d*) The difference between the highest and lowest value is not to exceed the equivalent of 20 Brinell numbers when the minimum specified tensile strength does not exceed 60 kg/mm^2 (38 ton/in^2) or 30 Brinell numbers when the minimum specified tensile strength is more than 60 kg/mm^2 (38 ton/in^2).

(*e*) On case hardened, nitrided or induction hardened components hardness tests are to be made on the teeth when surface hardening and grinding has been completed. The results are to comply with the approved values.

Sulphur Prints

(*f*) On forgings with integral journals and on pinion sleeves sulphur prints are to be taken over the whole surface and ends of the toothed portion.

On forgings for gear wheels and rims sulphur prints are to be taken from one of the end faces. At the discretion of the Surveyor additional prints may be requested from selected areas on the exterior surface.

When a system of batch testing is being employed the number of sulphur prints to be taken from each batch is to be agreed.

Magnetic Crack Detection

(*g*) The teeth of all components which have been case hardened, nitrided or induction hardened are to be examined by magnetic particle methods. This may be requested as a supplementary test on other items.

When current flow methods are used for magnetisation, particular care must be taken to avoid damaging the hardened surfaces by contact with the probes.

Depth of Hardened Zone

(*h*) On gear forgings where the teeth have been case hardened, nitrided or induction hardened additional test pieces may require to be processed with the forgings and subsequently sectioned to determine the depth of the hardened zone. These tests are to be carried out at the discretion of the Surveyor and for induction or case hardened gearing the depth of the hardened zone is to be in accordance with the approved specification or as otherwise agreed. For nitrided gearing the full depth of the hardened zone, i.e. depth to core hardness, is not to be less than 0,5 mm (0·020 in) and the hardness at a depth of 0,25 mm (0·010 in) is not to be less than 500 D.P.N. (*See* 621.)

Repair of Defects

628 The repair of defects by welding is not permitted.

Identification

629 Forgings are to be identified in accordance with Q 109.

Documentation

630 The manufacturer is to supply the information detailed in Q 110.

FERRITIC STEEL FORGINGS FOR TURBINES, COMPRESSORS AND TURBINE DRIVEN GENERATORS

Scope

631 Ferritic steel forgings for turbine rotors, discs and spindles, turbine driven generator rotors and compressor rotors are to be manufactured and tested in accordance with the requirements of this Section and the relevant parts of Q 1 and Q 2.

Orders and drawings for rotor forgings are to state whether the rotor is intended for propulsion or auxiliary machinery and the shaft horse power of auxiliary turbines. In the case of a rotor which is to be tested for thermal stability the maximum operating temperature and the proposed test temperature are also to be stated.

Where small and identical forgings are produced in large quantities, the Surveyor may adopt an alternative system of quality control provided it is approved and the required standard of inspection is maintained by the firm.

Manufacture

632 Forgings are to be manufactured in accordance with the requirements of 602 except that for rotor forgings the sectional area of any part (as forged) is not to exceed one half of the average sectional area of the ingot. Where an upsetting operation is included in the manufacturing procedure the above requirement is to apply to the sectional area of the upset bloom and not to the ingot.

Chemical Composition

633 The forgings may be made of carbon or alloy steel. For forgings in carbon steel the chemical composition is to comply with the following:—

Carbon	0,45% max.
Silicon	0,15 to 0,45%
Manganese	0,40% min.
Sulphur	0,050% max.
Phosphorus	0,050% max.

Where mechanical tests are required from forgings in either the radial or the tangential direction the sulphur and the phosphorus contents of the steel are not to exceed 0,040 per cent each.

Specifications of alloy steel forgings giving the proposed chemical composition, heat treatment and mechanical properties are to be submitted for approval with the plans of the components.

When it is proposed to use rotors of welded construction the compositions of the steels for the forgings are to be submitted for special consideration. These are to comply with the above limits of composition except that generally the carbon content is not to exceed 0,25 per cent.

Heat Treatment

634 Forgings are to be supplied in the heat treated condition and the thermal treatment at all stages is to be such as to avoid the formation of hair-line cracks. At a suitable stage of manufacture the forgings are to be re-heated above the upper critical point to refine the grain, cooled in an approved manner and then tempered to produce the desired mechanical properties.

Where forgings receive their main heat treatment before machining they are to be stress relieved after rough machining. Forgings heat treated in the rough machined condition need not be stress relieved provided that they have been slowly cooled from the tempering temperature.

The tempering and stress relieving temperatures are to be not less than 550°C in the case of carbon steels and 600°C in the case of alloy steels. The holding times and subsequent cooling rates are to be such that the forging in its final condition is free from harmful residual stresses.

If forgings are stress relieved after the mechanical tests have been taken the temperature used for this treatment is to be at least 20degC lower than the temperature previously used for tempering and the forgings are subsequently to be cooled at approximately the same rate as was used for cooling after tempering.

Details of the proposed heat treatment for rotors of welded construction are to be submitted for approval.

Test Material

635 At least one longitudinal tensile and one bend test piece are to be taken to represent the material of each forging (or multiple forging) excluding discs. In the case of forgings (or multiple forgings) exceeding both 3000 kg (3 tons) in weight and 2 m (6·5 ft) in length not less than one tensile and one cold bend test are to be taken from each end of each forging (or multiple forging) (*see* Fig. Q 6.5).

For rotor forgings of all main propulsion machinery and of auxiliary turbines exceeding 1500 shp tangential and, where dimensions permit, radial tensile and bend tests are also to be taken from the end of the body corresponding to the top end of the ingot (*see* Fig. Q 6.5).

For each turbine disc, at least one tensile and one bend test piece are to be cut in a tangential direction from material at the hub (*see* Fig. Q 6.6).

For this purpose, sufficient test material is to be left on each forging and is not to be removed until heat treatment has been completed except for stress relieving after rough machining as detailed in 634. In this connection a thermal stability test does not form part of the heat treatment of a turbine forging. Any excess test material is not to be completely severed from a forging until all the mechanical tests have been completed with satisfactory results.

Where a number of small forgings are made from one cast of steel and heat treated together in one furnace then a system of batch testing may be adopted. The number of tests required and the method of providing the test material is to be agreed with the Surveyor.

The dimensions of the tensile test pieces are to comply with Q 2 and they are to have a diameter of not less than 14 mm (0·564 in) except that if necessary the tangential and radial test pieces may be of smaller diameter, in all cases these should be as large as possible and of standard proportions.

Bend test pieces are to be machined to 20 mm by 10 mm in accordance with the subsidiary test piece defined in Q 206.

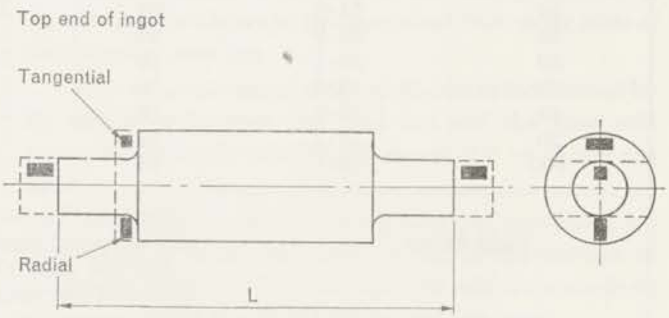


Fig. Q 6.5 Rotor Forgings

Two sets of longitudinal test pieces are required only when the length L exceeds 2 m (6·5 ft) and the weight exceeds 3000 kg (3 tons). Tangential and, where dimensions permit, radial test pieces from the body are required from rotor forgings for main propulsion machinery and for auxiliary turbines exceeding 1500 shp.

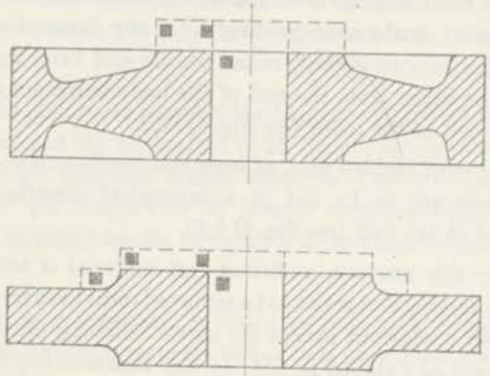


Fig. Q 6.6 Turbine Discs

Alternative positions for test pieces.

Mechanical Properties

636 The tensile strength of the forging is to comply with the range specified on the order. For carbon and carbon-manganese steel forgings the specified range of tensile strength is not to exceed 10 kg/mm² (6·3 ton/in²) within the general limits of 45 and 70 kg/mm² (28·6 and 44·5 ton/in²). For alloy steel rotor forgings the specified range is not to exceed 15 kg/mm² (9·5 ton/in²) within the general limits of 45 and 95 kg/mm² (28·6 and 60·3 ton/in²). For discs and other alloy steel forgings the specified range is not to exceed 15 kg/mm² (9·5 ton/in²) within the general limits of 45 and 115 kg/mm² (28·6 and 73 ton/in²).

When it is proposed to use a steel of higher tensile strength full details are to be submitted for approval.

The yield stress, percentage elongation and percentage reduction of area are to comply with the requirements of Table Q 6.5 appropriate to the specified minimum tensile strength of the steel.

The minimum angles and maximum diameters of formers for the bend tests are given in Table Q 6.5.

Inspection

637 *(a)* The Surveyor is to examine each forging before final acceptance at the forge.

(b) The forgemaster is to carry out an ultrasonic test on each forging and is to provide the Surveyor with a signed

TABLE Q 6.5

Mechanical Properties of Ferritic Steel Forgings for Turbines, Compressors and Generators

Specified Minimum Tensile Strength		Minimum Percentage Elongation for gauge length of $5{,}65\sqrt{S_o}$			Maximum diameter of former for bend test		
					180°	150°	120°
kg/mm²	ton/in²	Long.	Tan.	Rad.	Long.	Tan.	Rad.
45	28·6	24	20	17	2t	2t	2t
50	31·8	23	19	16	2t	2t	2t
55	34·9	22	17	15	$2\frac{2}{3}$t	$2\frac{2}{3}$t	$2\frac{2}{3}$t
60	38·1	19	16	14	4t	4t	4t
70	44·5	17	14	12	4t	4t	4t
80	50·8	16	12	10	4t	4t	4t
90	57·2	15	11	—	6t	6t	—
100	63·5	14	10	—	6t	6t	—
Yield Stress		Not less than 50% of the actual tensile strength for material in the normalised and tempered condition. Not less than 60% of the actual tensile strength for low alloy material in the quenched and tempered condition.					
Reduction of area		Not less than 35% for longitudinal tests. Not less than 30% for tangential tests. Not less than 20% for radial tests.					

Long. — For longitudinal tests
Tan. — For tangential tests
Rad. — For radial tests
t — Thickness of test piece.

Intermediate values are to be obtained by interpolation.

statement that such inspection has not revealed any significant internal defects.

(*c*) The end faces of the body of rotor forgings are to be machined to a fine smooth finish for visual and magnetic particle examination.

The end faces of the boss and the bore surface of each turbine disc are to be machined to a smooth finish and examined by a suitable method of magnetic crack detection.

(*d*) Rotor forgings for propulsion machinery and for auxiliary turbines exceeding 1500 shp are to be hollow bored for internal examination. The surface of the bore is to have a fine smooth finish and it is to be examined by means of an optical instrument of suitable magnification. Where the bore size permits, magnetic particle examination is also to be carried out. These examinations are to be confirmed by the Surveyor. Alternatively, an approved method of ultrasonic examination may be accepted instead of hollow boring. Details of the proposed method of ultrasonic examination are to be submitted for special consideration.

Thermal Stability Test

(*e*) Thermal stability tests after heat treatment and rough machining of the turbine rotors referred to in H 807 are to be undertaken in properly constructed furnaces, using accurate and reliable measuring equipment. Each test is to be carried out in accordance with the following recommended procedure:—

(i) Five bands are to be machined concentric with the axis of rotation. Two of these are to be reference bands and are to be positioned at or near the locations of the bearings. The remaining three bands are to be test bands located one as near as possible to the mid-length, and the other two near each end of the body. Where the length of a rotor is such that five bands cannot be provided, alternative proposals are to be submitted to the Surveyor for his approval.

(ii) Four positions, 90° apart, are to be stamped A, B, C and D, on the coupling end of the rotor.

(iii) The whole of the body and as much of the shaft at either end as will include the positions of the glands are to be enclosed in the furnace. In the case of a rotor having an overhung astern wheel, the astern wheel is also to be enclosed in the furnace during the first test (*see* H 807).

(iv) The rotor is to be rotated at a uniform and very slow speed.

(v) The deflections at all bands are to be recorded at the A, B, C and D positions. Initial cold readings are to be taken prior to heating.

(vi) The rotor is to be heated uniformly and slowly. Temperatures are to be recorded continuously at the surface of the rotor and if practicable in the bore at the mid-length of the body. Under no circumstances is the surface temperature to exceed the temperature at which the rotor was tempered. During heating the rate of rise of temperature is to be such as to avoid excessive temperature gradients in the rotor.

(vii) The maximum or holding temperature is to be not less than 28degC (50degF) above the maximum operating temperature of the rotor. For the purposes of the test the holding period is to start when the rotor has attained a uniform and specified temperature. The rotor is to be held under the specified temperature conditions until not less than three consecutive hourly readings of deflections show the radial eccentricity to be constant within 0,006 mm (0·00025 in) on all test bands.

(viii) The turbine rotor is to be rotated during cooling until the temperature is not more than 100°C (212°F). The rate of cooling is to be such as to avoid excessive temperature gradients in the rotor.

(ix) Final cold readings are to be taken.

The movements of the axis of the rotor in relation to the reference bands are to be determined from polar plots of the deflection readings.

The radial movement of the shaft axis as determined by the difference between the final hot and the final cold movements is not to exceed 0,025 mm (0·001 in) on any one band.

As verification that test equipment and conditions are satisfactory it is required that similar determinations of differences between initial cold and final cold movements do not exceed 0,025 mm (0·001 in) on any one band.

If the results of the test on a rotor fail to meet either or both of the above requirements, the test may be repeated if requested by the maker and agreed by the Surveyor.

In the case of a rotor failing to meet the requirements of a thermal stability test, the rotor is deemed unacceptable. Proposals for the rectification of thermal instability of a rough machined rotor are to be submitted for special consideration.

Repair of Defects

638 The repair of defects by welding is not permitted.

Identification

639 Forgings are to be identified in accordance with Q 109.

Documentation

640 The manufacturer is to supply the information detailed in Q 110 and a certificate of ultrasonic examination as required by 637(*b*).

FORGINGS FOR BOILERS AND PRESSURE VESSELS

Scope

641 Forged seamless drums, headers and other forgings intended for boilers and pressure vessels are to be manufactured and tested in accordance with the requirements of this Section and the relevant parts of Q 1 and Q 2. For pressure vessels containing radio-active materials or gases additional requirements may be specified.

Provision is made for three categories of forgings which differ mainly in respect of testing procedure and are intended for the following uses:—

Category I	Where design is based on guaranteed values for elevated temperature properties.
Category II	Where design is based on nominal values for elevated temperature properties which are not required to be proved by tests.
Category III	For pressure vessels intended for special low temperature service where the steel is to have guaranteed low temperature Charpy V-notch impact properties. In this case the proposed specification is to be submitted for approval.

Alternative specifications may be accepted provided they give reasonable equivalents to the requirements of this Section.

Where small and identical forgings are produced in large quantities, the Surveyor may adopt an alternative system of quality control provided it is approved and the required standard of inspection is maintained by the manufacturer.

Manufacture

642 Forgings are to be manufactured in accordance with the requirements of 602.

Seamless drums and headers are to be forged from ingots or forged blooms which have been punched, bored or trepanned. Alternatively, where specially approved, hollow cast ingots may be used. The wall of the hollow ingot or bloom is to be reduced in thickness by at least two-thirds during subsequent forgings. Other proposals are to be submitted for approval.

Chemical Composition

643 For Categories I or II the chemical composition of the steel is to comply with the requirements of Table Q 3.1 except that the steel is to be killed.

For Category III the chemical composition is to comply with the requirements of the approved specification.

Heat Treatment

644 All carbon and carbon-manganese steel forgings are to be normalised or normalised and tempered. All alloy steel forgings are to be normalised and tempered.

If required by the Surveyors or by the fabricators test material may be given a simulated stress relieving heat treatment prior to the preparation of the test pieces. This has to be stated on the order together with agreed details of the simulated heat treatment and the mechanical properties, which can be expected.

Test Material

645 (*a*) *Category I.* Tensile and bend tests are to be made at ambient temperature on material from each forging.

On seamless drums and headers, which are initially forged with open ends, test material is to be provided at each end of each forging. On seamless drums or headers, forged with one solid end, test material is to be provided at the open end only. Except where the ends are to be subsequently closed by forging, the test material is not to be removed until heat treatment has been completed. Where the ends are to be closed, rings of test material are to be cut off prior to the closing operation and are to be heat treated with the finished forging. In all cases the test pieces are to be cut in a circumferential direction.

In addition to the tests at ambient temperature, one tensile test at elevated temperature is to be made to represent each drum or header forging. This test piece is to be taken from the end which gave the lower tensile value at ambient temperature.

For forgings other than seamless drums and headers test material is to be provided for tensile and bend tests at ambient temperature in accordance with 605. In addition, one tensile test at elevated temperature is to be made from each forging or for each batch of forgings.

Tensile tests at elevated temperature are not required when:—

(i) the reference test temperature is 100°C or less,

(ii) the specified minimum value of the 0,2 per cent proof stress value at the reference test temperature is higher than the corresponding stress-to-rupture value,

(iii) the actual tensile strength at ambient temperature exceeds by at least 4 kg/mm^2 (2·5 ton/in^2) the minimum specified tensile strength. This applies only to carbon and carbon-manganese steels.

(*b*) *Category II.* Test material is to be provided for the tests at ambient temperature specified for Category I. Tests at elevated temperatures are not required.

(*c*) *Category III.* On seamless drums and headers test material is to be provided for the tests at ambient temperature specified for Category I. In addition, three Charpy V-notch test pieces are to be prepared from each end except for drums or headers forged with one solid end, when impact tests are required from the open end only.

For forgings other than seamless drums and headers test material is to be provided for the tests at ambient temperature specified for Category I and, in addition, Charpy V-notch test pieces are to be taken from each forging or from each batch of forgings when specified.

(*d*) The dimensions of the tensile test pieces are to comply with the requirements of Q 2. Test pieces for ambient temperature tests are to have a diameter of not less than 14 mm (0·564 in) unless the thickness of the test material is insufficient, in which case the diameter is to be as large as possible.

Bend test pieces are to be in accordance with Q 2.

Charpy V-notch test pieces are to be machined in accordance with the dimensions given in Q 2.

Mechanical Tests

646 (*a*) *Category I.* The results of all tensile tests are to comply with the values given in Table Q 6.6. The lower yield or 0,2 per cent proof stress values at elevated temperatures are to be determined at the reference test temperature given in the order and are to comply with the values given in the above Table or as otherwise agreed with the manufacturer.

Bend test pieces are to withstand being bent through an angle of 180° round a former having a diameter not greater than that specified in Table Q 6.6.

Stress rupture values for design purposes are given in Table Q 3.5.

(*b*) *Category II.* The results of all tensile tests at ambient temperature are to comply with the values given in Table Q 6.7.

Bend test pieces are to withstand being bent through an angle of 180° round a former having a diameter not greater than that specified in Table Q 6.7.

For design purposes nominal values of the lower yield or 0,2 per cent proof stress at elevated temperatures are given in Table Q 6.7 and stress rupture values in Table Q 3.5.

(*c*) *Category III.* The results of all tensile, bend and impact tests are to comply with the approved specification. The Charpy V-notch tests are to be made at or below the approved reference test temperature.

Inspection

647 The Surveyor is to examine each forging before final acceptance at the forge.

On seamless drums sulphur prints may be requested to demonstrate that sufficient ingot discard has been taken.

When a number of separate small forgings are tested as a batch, the hardness of each forging is to be determined including those from which material is to be cut for the provision of tensile, bend and Charpy test pieces. The hardness of the forgings are to comply with a specification approved by the Surveyor before manufacture of the forgings. The Surveyor is to satisfy himself that the inspection procedure for surface condition and soundness adopted by the manufacturer is adequate.

Repair of Defects

648 The repair of minor surface defects in accordance with Q 108 will be considered.

Identification

649 Forgings are to be identified in accordance with Q 109.

Documentation

650 The manufacturer is to supply the information detailed in Q 110.

TABLE Q 6.6

Mechanical Properties of Forgings for Boilers and Pressure Vessels Category I

Grade of Steel	Yield Stress Minimum kg/mm^2	Tensile Strength kg/mm^2	Elongation on $5{,}65\sqrt{So}$ % Minimum	Bend Test Maximum diameter of former	Minimum Lower Yield or 0,2 % Proof Stress, kg/mm^2										
					100°C	150°C	200°C	250°C	300°C	350°C	400°C	450°C	500°C	550°C	600°C
Carbon and Carbon-Manganese	18,4	37–47	25	2t	16,7	15,7	14,6	13,9	12,9	12,1	11,3	10,9			
	20,9	42–52	23	2t	19,2	18,3	17,2	16,4	15,4	14,6	13,9	13,4			
	23,5	47–57	21	3t	21,7	20,8	19,7	18,9	17,9	17,2	16,4	15,9			
	26,0	52–62	20	3t	24,3	23,3	22,2	21,4	20,5	19,7	18,9	18,4			
1Cr–½Mo	23,6	42–52	23	3t	22,8	22,0	21,3	19,1	16,7	15,1	14,8	14,5	14,2		
2¼Cr–1Mo	39,4	55–68	18	3t	36,1	34,5	33,7	33,2	32,9	32,6	32,0	30,3	27,5	22,0	

t = thickness of bend test piece.

or in British units:—

TABLE Q 6.6

Mechanical Properties of Forgings for Boilers and Pressure Vessels Category I

Grade of Steel	Yield Stress Minimum ton/in²	Tensile Strength ton/in²	Elongation $5 \cdot 65\sqrt{So}$ % Minimum	Bend Test Maximum diameter of former	Minimum Lower Yield or 0·2 % Proof Stress— $\frac{\text{ton/in}^2}{\text{lb/in}^2}$										
					100°C	150°C	200°C	250°C	300°C	350°C	400°C	450°C	500°C	550°C	600°C
Carbon and Carbon-Manganese	11·7	23·5–29·8	25	2t	10·6 23 700	10·0 22 400	9·3 20 800	8·8 19 700	8·2 18 400	7·7 17 200	7·2 16 100	6·9 15 500			
	13·3	26·7–33·0	23	2t	12·2 27 300	11·6 26 000	10·9 24 400	10·4 23 300	9·8 22 000	9·3 20 800	8·8 19 700	8·5 19 000			
	14·9	29·8–36·2	21	3t	13·8 30 900	13·2 29 600	12·5 28 000	12·0 26 900	11·4 25 500	10·9 24 400	10·4 23 300	10·1 22 600			
	16·5	33·0–39·4	20	3t	15·4 34 500	14·8 33 200	14·1 31 600	13·6 30 500	13·0 29 100	12·5 28 000	12·0 26 900	11·7 26 700			
1Cr–½Mo	15·0	26·7–33·0	23	3t	14·5 32 400	14·0 31 300	13·5 30 200	12·1 27 100	10·6 23 800	9·6 21 500	9·4 21 100	9·2 20 600	9·0 20 200		
2¼Cr–1Mo	25·0	34·9–43·2	18	3t	22·9 51 300	21·9 49 100	21·4 47 900	21·1 47 300	20·9 46 800	20·7 46 400	20·3 45 500	19·2 43 000	17·5 39 200	14·0 31 400	

t = thickness of bend test piece

TABLE Q 6.7

Mechanical Properties of Forgings for Boilers and Pressure Vessels Category II

Grade of Steel	Yield Stress Minimum kg/mm^2	Tensile Strength kg/mm^2	Elongation on $5,65\sqrt{So}$ % Minimum	Bend Test Maximum diameter of former	Lower Yield or 0,2 % Proof Stress, kg/mm^2 (Note 1)										
					100°C	150°C	200°C	250°C	300°C	350°C	400°C	450°C	500°C	550°C	600°C
Carbon and Carbon-Manganese	18,4	37–47	25	2t	14,8	14,5	14,2	12,8	11,2	9,6	9,4	9,4			
	20,9	42–52	23	2t	18,0	17,6	17,3	15,8	14,2	12,6	12,3	12,0			
	23,5	47–57	21	3t	21,0	20,8	20,3	18,6	17,0	15,4	14,5	13,5			
	26,0	52–62	20	3t	24,1	23,8	23,1	21,4	19,9	18,3	16,5	15,0			
1Cr–½Mo	23,6	42–52	23	3t	19,5	18,7	18,1	16,2	14,2	12,8	12,6	12,3	12,1		
2¼Cr–1Mo	39,4	55–68	18	3t	30,7	29,3	28,6	28,2	27,9	27,7	27,2	25,7	23,4	18,7	

t = thickness of bend test piece

NOTE 1. The values for yield stress or 0,2 per cent proof stress at elevated temperatures are given for design purposes and do not have to be proved by test.

or in British units:—

TABLE Q 6.7

Mechanical Properties of Forgings for Boilers and Pressure Vessels Category II

Grade of Steel	Yield Stress Minimum ton/in^2	Tensile Strength ton/in^2	Elongation on $5\cdot65\sqrt{So}$ % Minimum	Bend Test Maximum diameter of former	Lower Yield or 0·2% Proof Stress, lb/in^2 (Note 1)										
					100°C	150°C	200°C	250°C	300°C	350°C	400°C	450°C	500°C	550°C	600°C
Carbon and Carbon-Manganese	11·7	23·5–29·8	25	2t	21 100	20 600	20 200	18 200	15 900	13 700	13 400	13 400			
	13·3	26·7–33·0	23	2t	25 600	25 000	24 600	22 500	20 200	17 900	17 500	17 100			
	14·9	29·8–36·2	21	3t	29 900	29 600	28 900	26 500	24 200	21 900	20 600	19 200			
	16·5	33·0–39·4	20	3t	34 300	33 900	32 900	30 400	28 300	26 000	23 500	21 300			
1Cr–½Mo	15·0	26·7–33·0	23	3t	27 700	26 600	25 700	23 000	20 200	18 200	17 900	17 500	17 200		
2¼Cr–1Mo	25·0	34·9–43·2	18	3t	43 600	41 700	40 700	40 200	39 800	39 400	38 700	36 600	33 300	26 700	

t = thickness of bend test piece.

NOTE 1. The values for yield stress or 0·2 per cent proof stress at elevated temperatures are given for design purposes and do not have to be proved by test.

STEEL TUBES AND PIPES

Scope

701 (*a*) Boiler tubes, superheater tubes and pipes intended for use in the construction of boilers and pressure vessels are to be manufactured and tested in accordance with the requirements of this Section and the relevant parts of Q 1 and Q 2. These requirements are also applicable to pressure pipes intended for the services detailed in E 508 and for special low temperature service. Pressure pipes other than those mentioned in E 508 and having a design pressure of not less than 7 kg/cm² (100 lb/in²) may be made and tested to the requirements of this Section, or alternatively, may be in accordance with an approved national specification except that forge butt welded pipes are not acceptable. (*See* E 508, quoted at end of this Section).

Pressure pipes, when available in suitable sizes, may be used for the manufacture of seamless pressure vessels or headers and in such cases the requirements for forgings given in Q 643 to Q 650 would be applicable.

Provision is made for four categories which differ mainly in respect of testing procedures and are intended for the following uses:—

Category I	Where design is based on guaranteed values for elevated temperature properties.
Category II	Where design is based on nominal values for elevated temperature properties which are not required to be proved by test.
Category III(a)	For special low temperature service where the steel is required to have guaranteed low temperature Charpy V-notch impact properties. This category is not applicable to material with a thickness under 3 mm (0·12 in).
Category III(b)	For similar service where fine grain steels are acceptable without proving the low temperature impact properties by acceptance tests.

For Category III(a) and III(b) material, the proposed specification is to be submitted for approval.

(*b*) Orders should indicate the category of material required and if intended for use as boiler tubes, superheater tubes, or pressure pipes. For Categories I and III the reference test temperature is also to be given (*see* Q 101(c)).

(*c*) At the discretion of the Surveyor, a modified testing procedure may be adopted for small quantities of material. In such cases short lengths may be accepted on the manufacturer's declared chemical composition and hardness tests or other evidence of satisfactory properties.

(*d*) Alternatively, steel tubes or pipes which comply with national or proprietary specifications may be accepted provided these specifications give reasonable equivalence to the requirements of this section.

Manufacture

702 (*a*) For Category I the steel is to be either silicon or aluminium killed. (*See* Table Q 7.1).

For Category II any method of deoxidation may be used except that rimming steel may only be used for design temperatures not exceeding 400°C (750°F).

For Category III the method of deoxidation is to be in accordance with the approved specification.

(*b*) Tubes and pipes may be manufactured by any of the following methods unless one of these methods is particularly specified on the order:—

Hot Finished Seamless,
Cold Finished Seamless,
Electric Resistance Welded,
Cold Finished Electric Resistance Welded,
Electric Fusion Welded (austenitic stainless steel only).

If rimming steel strip is used for the manufacture of electrical resistance welded tubes or pipes, the strips are to be rolled in single widths and not slit longitudinally.

For Category III the method of manufacture is to be included in the specification submitted for approval.

(*c*) Care is to be taken that any non-ferrous metals or their compounds coming into contact with the tubes or pipes during manufacture are not deposited so as to be harmful during subsequent fabrication and operation.

Chemical Composition

703 For Categories I and II the chemical composition is to comply with the requirements given in Table Q 7.1.

The chemical composition of steel for Category III is to comply with the approved specification.

Heat Treatment

704 For Categories I and II tubes and pipes are to be supplied in the condition detailed in Table Q 7.2.

For Category III the heat treatment is to comply with the approved specification.

Test Material

705 (*a*) Tests are to be made on straight tubes and pipes after completion of all drawing and heat treatment operations.

(*b*) *Category I*. Tubes and pipes are to be presented for test in batches. Each batch is to contain not more than 400

lengths when outside diameter is not more than 114,3 mm (4·5 in) or not more than 200 lengths when the outside diameter is more than 114,3 mm (4·5 in).

Where heat treatment has been carried out, a batch is to consist of tubes or pipes of the same size, manufactured from the same cast of steel and subjected to the same finishing treatment in a continuous furnace or heat treated in the same furnace charge in a batch type furnace.

Where no heat treatment has been carried out, a batch is to consist of tubes or pipes of the same size manufactured from the same cast of steel and by the same process of manufacture.

At least 2 per cent of the number of lengths in each batch are to be selected at random for the preparation of tests at ambient temperature. Each boiler tube selected for test is to be subjected to tensile, flattening and expanding tests. The expanding test is to be made at each end of each sample length.

Each pressure pipe selected for test is to be subjected to tensile and flattening or bend tests.

(*c*) Tensile tests at elevated temperature are to be taken from each cast unless the weight of finished material is greater than 30 000 kg (30 tons) in which case one extra test is to be taken from each 30 000 kg (30 tons) or fraction thereof.

These tensile tests at elevated temperature are not required when:—

(i) the reference test temperature is 100°C or less,

(ii) the minimum specified value of the 0,2 per cent proof stress value at the reference test temperature is higher than the corresponding stress-to-rupture value,

(iii) the actual tensile strength at ambient temperature exceeds by at least 5 kg/mm^2 (3·2 ton/in^2) the minimum specified tensile strength. This applies only to carbon and carbon-manganese steels,

(iv) the manufacturer has obtained certification of elevated temperature proof stress values as detailed in 706(*d*).

(*d*) *Category II*. Tubes and pipes are to be presented for test in batches. Each batch is to contain not more than the number of lengths permitted in Category I but may consist of tubes or pipes of the same size, manufactured by the same method from material of the same specification.

Tests at ambient temperature are to be taken as for Category I. Tensile tests at elevated temperature are not required.

(*e*) *Category III*. Tubes and pipes are to be presented for test in batches and tests taken in accordance with the requirements for Category I except that tests at elevated temperatures are not required. In addition for Category III(a) material a set of three Charpy V-notch test pieces is to be taken from each batch. When the wall thickness is insufficient to permit the preparation of standard Charpy test pieces then the largest possible subsidiary test piece is to be prepared, *see* Q 208.

(*f*) All test pieces are to be prepared in accordance with the requirements of Q 2.

Mechanical Properties

706 (*a*) *Category I*. The results of all tensile tests are to comply with the values given in Table Q 7.3. The lower yield or 0,2 per cent proof stress values at elevated temperature are to be determined in accordance with Q 205 at the reference test temperature given in the order.

The flattening test for boiler and superheater tubes and for pressure pipes is to be carried out in accordance with Q 209. The test is to be continued until the distance between the platens, measured under load is not greater than the value given by the formula:—

$$H = \frac{t(1 + c)}{c + \frac{t}{D}}$$

where H = distance between platens, in mm (in),

t = specified thickness of the tube, in mm (in),

D = specified outside diameter of the tube, in mm (in),

c = a constant depending on the steel.

Steel	*Values for* c
Carbon 33/45	0,09
35/47	0,09
42/54	0,07
1Cr ½Mo	0,08
2¼Cr 1Mo	0,08
½Cr ½Mo ¼V	0,08
17, 13 Mo	0,09
18, 12 Nb	0,09
18, 10 Ti	0,09

For pressure pipes, bend tests may be taken as an alternative for flattening tests and are to be carried out in accordance with Q 207. The test pieces are to withstand being bent through an angle of 180° round a former having a diameter not greater than that specified in Table Q 7.3.

The drift expanding test specified for boiler and superheater tubes is to be carried out in accordance with Q 210. The test is to be continued until the increase in outside diameter is not less than the values given below.

Outside diameter	*Minimum increase per cent*
Up to and including 63,5 mm (2·5 in)	17
Over 63,5 mm (2·5 in)	11

Stress rupture values for design purposes are given in Table Q 7.5.

(*b*) *Category II*. The results of tensile tests at ambient temperature are to comply with the values given in Table Q 7.4. For design purposes, nominal values of the yield or 0,2 per cent proof stress at elevated temperatures are given in Table Q 7.4. Stress rupture values are given in Table Q 7.5.

Expanding and flattening or bend tests are to be carried out as specified for Category I, the maximum diameter of the former for the bend test is given in Table Q 7.4.

(*c*) *Category III*. The Charpy V-notch tests are to be made at or below the reference test temperature given in the order. The results of the tensile, Charpy V-notch and flattening or bend tests are to comply with the approved specification.

Certification of Lower Yield or 0,2 per cent Proof Stress Values at Elevated Temperatures

(*d*) For Category I material or other approved grades as an alternative to taking tensile tests at elevated temperature in accordance with 705(*c*) individual manufacturers may submit for analysis and approval comprehensive test data for a specific grade of steel to demonstrate the lower yield or 0,2 per cent proof stress values at elevated temperatures which can be consistently obtained. This data will be assessed on a statistical basis to determine the 95 per cent lower confidence limit. When a manufacturer is approved on this basis routine tensile tests at elevated temperature will not be required except for periodic check tests at the discretion of the Surveyors.

Manufacturers requiring this form of certification are to submit the following information and test data from at least 45 batches taken from not less than 10 different casts for each grade of steel:—

(1) Ladle analysis including residual elements,
(2) Method of deoxidation,
(3) Method of manufacture,
(4) Details of heat treatment,
(5) Results of tensile tests at ambient temperature:— Yield stress, tensile strength and percentage elongation,
(6) Results of tensile tests at elevated temperatures:— Lower yield or 0,2 per cent proof stress values at 100, 150, 200, 250, 300, 350, 400, 450°C or higher if appropriate for the grade of steel being tested.
(7) Thickness of tubes or pipes.

The test data are to be representative of the tensile range specified for the grade and also the range of thickness which will be manufactured. For carbon and carbon-manganese steels where there is an overlap in the specified tensile strength range, data submitted for one grade may also be considered for adjacent grades provided the properties at ambient temperature comply with the appropriate tensile strength range.

Inspection

707 (*a*) The tubes and pipes are to be straight, smooth and cylindrical within practical limits. The ends are to be cut square with the axis and are to be ground where necessary to facilitate examination.

They are to be presented for examination under adequate conditions of lighting and are to be examined internally and externally.

(*b*) In the case of welded tube or pipe the manufacturer is to employ suitable non-destructive methods for the quality control of the weld. It is preferred that this examination is carried out on a continuous basis.

Dimensional Tolerances of Pressure Pipes

(*c*) The thickness and diameter of each pressure pipe is to be within the following tolerances:—

(i) *Hot Finished Seamless*

	Ratio of thickness to outside diameter		Tolerance
Thickness	up to and including 3%		±15%
	over 3% and up to 10%		±12,5%
	over 10%	up to and including 168,3 mm (6⅝ in) o.d.	±12,5%
		over 168,3 mm (6⅝ in) o.d.	±10%
Outside diameter	Tolerance ±1% with a minimum of ±0,5 mm (0·02 in)		

(ii) *Cold Finished Seamless*

SIZE	Up to and including 219,1 mm ($8\frac{5}{8}$ in) o.d.	over 204 mm (8 in) i.d.	
TOLERANCE ON THICKNESS	±10%	up to and including 6,3 mm ($\frac{1}{4}$ in) thick	+15% −0%
		over 6,3 mm ($\frac{1}{4}$ in) thick	+10% −0%
TOLERANCE ON INSIDE DIAMETER	—	+0,8 mm ($\frac{1}{32}$ in) −1,6 mm ($\frac{1}{16}$ in)	
TOLERANCE ON OUTSIDE DIAMETER	±1%	—	

(iii) *Electric Resistance Welded*

THICKNESS (except at weld)	TOLERANCE
Up to and including 139,7 mm ($5\frac{1}{2}$ in) o.d.	±7,5%
Over 139,7 mm ($5\frac{1}{2}$ in) o.d.	±10%
OUTSIDE DIAMETER	±1% with a minimum of ±0,5 mm (0·02 in)

NOTE:—At the weld the external fin is to be removed completely, i.e. flush with the outside surface of the pipe. Where practicable, the internal fin is to be removed throughout the length of the pipe so that its maximum height shall not exceed 8% of the specified thickness or 0,25 mm (0·01 in) whichever is the greater.

Dimensional Tolerances of Boiler and Superheater Tubes

(*d*) The thickness and diameter of each tube is to be within the following tolerances which apply only to plain tubes:—

(i) *Hot Finished Seamless*

THICKNESS	Tolerance ±12,5%
OUTSIDE DIAMETER	±1% with a minimum of ± 0,5 mm (0·02 in)

(ii) *Cold Finished Seamless: Carbon and Low Alloy Steel: Cold Finished Electric Resistance Welded: Carbon and Low Alloy Steel*

THICKNESS	Tolerance ±7,5%
OUTSIDE DIAMETER	±0,5% with a minimum of ±0,1 mm (0·004 in)

(iii) *Cold Finished Seamless: Austenitic Steel*

THICKNESS	TOLERANCE
up to and including 3,2 mm (0·128 in)	±10%
over 3,2 mm (0·128 in)	±7,5%
OUTSIDE DIAMETER	±0,5% with a minimum of 0,15 mm± (0·006 in)

(iv) *Electric Resistance Welded*

THICKNESS (except at weld)	TOLERANCE
up to and including 3,2 mm (0·128 in)	±10%
over 3,2 mm (0·128 in)	±7,5%
OUTSIDE DIAMETER	±0,75% with a minimum of ±0,3 mm (0·012 in)

NOTE:—At the weld the external fin is to be removed completely, i.e. flush with the outside surface of the tube. The internal fin is also to be removed throughout the length of the tube so that the maximum height of fin is not greater than 0,25 mm (0·010 in).

Hydraulic Tests

(*e*) Each boiler or superheater tube and each pressure pipe is to be subjected to a hydraulic test at the manufacturer's works. The test pressure is to be maintained for sufficient time to permit proof and inspection. Unless otherwise agreed, the manufacturer's certificate of satisfactory hydraulic test may be accepted.

The test pressure is to be 1,5 times the design pressure or 70 kg/cm² (1000 lb/in²) whichever is the greater. The test pressure is not, however, to exceed that calculated from the formula

$$P = \frac{200\,s\,t}{D} \qquad \left(P = \frac{4480\,s\,t}{D}\right)$$

where P = test pressure, in kg/cm² (lb/in²),

D = nominal outside diameter, in mm (in),

t = nominal wall thickness, in mm (in),

$s = 0{,}40 \times$ minimum specified tensile strength, in kg/mm² (ton/in²).

Repair of Defects

708 The repair of minor defects by welding can be accepted subject to compliance with the requirements of Q 108.

Identification

709 Tubes and pipes are to be identified in accordance with Q 109. It is recommended that hard stamping be restricted to the end face but may be accepted in other positions in accordance with national standards and practice.

Documentation

710 The manufacturer is to supply the information detailed in Q 110.

Extract from Chapter E for reference

Steel Pipes

E 508 Steel pipes for a design pressure exceeding 17,5 kg/cm² (250 lb/in²) or a temperature exceeding 220°C (428°F), and all feed pipes and pressure pipes conveying heated oil are to be manufactured and tested in accordance with the requirements of Q 7. Where it is proposed to use materials for pipes other than shown in Q 7, the information called for in E 511 (a) is to be submitted for consideration.

TABLE Q 7.1

Chemical Composition of Tubes and Pipes

Grade of Steel	Tensile Stress		Method of Deoxidation	Chemical Composition of Ladle Samples—Percentage										
	kg/mm²	ton/in²		C	Si	Mn	S	P	Residual Elements					
Carbon	35–47	22·2–29·8	Silicon or aluminium killed	0,20 max.	0,10–0,35	0,40–0,90	0,050 max.	0,050 max.	Ni 0,30 max. Cr 0,25 max. Mo 0,10 max. Cu 0,30 max. Total 0,70 max.					
Category I	42–54	26·7–34·3		0,25 max.	0,10–0,35	0,40–1,00	0,050 max.	0,050 max.						
Carbon	33–45	21·0–28·6	Any method but see Note 1 for rimmed steel	0,18 max.	—	0,30–0,70	0,050 max.	0,050 max.						
	35–47	22·2–29·8		0,20 max.	0,35 max.	0,30–0,90	0,050 max.	0,050 max.						
Category II	42–54	26·7–34·3		0,25 max.	0,35 max.	0,30–1,00	0,050 max.	0,050 max.						
									Ni	Cr	Mo	Cu	V	Sn
LOW ALLOY 1Cr–½Mo	42–63	26·7–40·0	Silicon killed	0,10–0,15	0,10–0,35	0,40–0,70	0,040 max.	0,040 max.	0,30 max.	0,70–1,10	0,45–0,65	0,25 max.	—	0,03 max.
2¼Cr–1Mo	42–57 50–70	26·7–36·2 31·7–44·4		0,08–0,15	0,10–0,50	0,40–0,70	0,040 max.	0,040 max.	0,30 max.	2,00–2,50	0,90–1,20	0,25 max.	—	0,03 max.
½Cr–½Mo–¼V	47–62	29·8–39·4		0,15 max.	0,10–0,35	0,40–0,70	0,040 max.	0,040 max.	0,30 max.	0,25–0,50	0,50–0,70	0,25 max.	0,22–0,30	0,03 max.
HIGH ALLOY 17–13–Mo	52–67	33·0–42·5		0,04–0,09	0,75 max.	1,00–2,00	0,030 max.	0,040 max.	12,0–14,0	16,0–17,5	2,00–2,75	—	—	—
18–12–Nb (Note 2)	52–67	33·0–42·5		0,04–0,09	0,20–0,80	0,50–2,00	0,030 max.	0,040 max.	11,0–13,0	17,0–19,0	—	—	—	—
18–10–Ti (Note 3)	52–67	33·0–42·5		0,04–0,09	0,20–0,80	0,50–2,00	0,030 max.	0,040 max.	9,0–13,0	17,0–20,0	—	—	—	—

NOTES: 1. Rimmed steel is only to be used for applications where the design temperature does not exceed 400°C (750°F).

2. Niobium+Tantalum. Minimum 10×% Carbon. Maximum 1,10%.

3. Titanium. Minimum 4×% Carbon. Maximum 0,60%.

TABLE Q 7.2

Heat Treatment of Tubes and Pipes

GRADE OF STEEL	CONDITION OF SUPPLY	CATEGORY
CARBON		
Hot Finished Seamless... ...	As rolled or ... ... (Note 1) Normalised 880/920°C ... ... (Note 2)	I & II I & II
Cold Finished Seamless ...	Annealed or ... ... (Note 3) Normalised 880/920°C ... ... (Note 2)	II I & II
Electric Resistance Welded ...	Normalised 880/920°C ... ... (Note 2)	I & II
Cold Finished E.R.W.	Normalised 880/920°C ... ... (Note 2)	I & II
ALLOY STEEL		
1Cr–½Mo	Normalised 900/960°C Tempered 640/690°C ...	I & II
2¼Cr–1Mo	Annealed 920/960°C or ... ... (Note 4) Normalised 920/960°C Tempered 650/750°C ... (Note 5)	I & II I & II
½Cr–½Mo–¼V	Normalised 950/980°C Tempered 660/710°C ... (Note 6)	I & II
17–13–Mo	Solution treated 1 050/1 100°C	I & II
18–12–Nb	Solution treated 1 070/1 120°C	I & II
18–10–Ti	Solution treated 1 090/1 140°C	I & II

NOTES

1. Provided the hot finishing temperature is sufficiently high to soften the material.

2. At the option of the manufacturer tubes and pipes may also be tempered after normalising.

3. Annealed tubes and pipes are only to be used for applications where the design temperature does not exceed 400°C (750°F).

4. Where the cooling rate from annealing temperature exceeds 100degC per hour, the material is to be tempered at 650/700°C.

5. For tempering temperatures of 720°C or higher, the time above this temperature is not to exceed 30 minutes.

6. Time at tempering temperature is to be not less than 3 hours.

TABLE Q 7.3

Mechanical Properties of Tubes and Pipes Category I

Grade of Steel	Yield Stress Minimum kg/mm²	Tensile Strength kg/mm²	Elongation on $5{,}65\sqrt{So}$ % Minimum	Bend Test Maximum diameter of former	Minimum Lower Yield Stress or 0,2 % Proof Stress, kg/mm²										
					100°C	150°C	200°C	250°C	300°C	350°C	400°C	450°C	500°C	550°C	600°C
Carbon	21,3	35–47	27	3t	18,6	18,4	18,0	17,0	14,8	13,2	12,0	11,7			
Carbon	25,2	42–54	23	4t	20,5	20,2	19,4	18,3	16,1	14,6	14,0	13,4			
1Cr–½Mo	23,6	42–63	17	4t	22,9	22,0	21,3	19,1	16,7	15,1	14,8	14,5	14,2		
2¼Cr–1Mo (Note 1)	23,6	42–57	20	4t	20,0	18,1	15,6	15,1	14,6	14,0	13,5	13,2	12,8	12,3	
2¼Cr–1Mo (Note 2)	26,8	50–70	16	4t	25,8	25,5	25,0	24,0	23,0	22,0	21,0	20,0	19,0		
½Cr–½Mo–¼V	30,0	47–62	20	4t	25,8	25,5	25,0	24,0	23,0	22,0	21,0	20,0	19,0		
17–13–Mo	19,0	52–71	30	3t											
18–12–Nb	21,0	52–71	30	3t											
18–12–Ti	17,0	52–71	30	3t											

t = thickness of bend test piece.

NOTES: 1. Annealed condition.

2. Normalised and tempered condition.

or in British units:—

TABLE Q 7.3

Mechanical Properties of Tubes and Pipes Category I

Grade of Steel	Yield Stress Minimum ton/in²	Tensile Strength ton/in²	Elongation on $5 \cdot 65\sqrt{So}$ % Minimum	Bend Test Maximum diameter of former	Minimum Lower Yield Stress or 0·2% Proof Stress, $\frac{\text{ton/in}^2}{\text{lb/in}^2}$										
					100°C	150°C	200°C	250°C	300°C	350°C	400°C	450°C	500°C	550°C	600°C
Carbon	13·5	22·2–29·8	27	3t	11·8 26 500	11·7 26 200	11·4 25 600	10·8 24 200	9·4 21 100	8·4 18 800	7·6 17 100	7·4 16 600			
Carbon	16·0	26·7–34·3	23	4t	13·0 29 200	12·8 28 700	12·3 27 600	11·6 26 000	10·2 22 900	9·3 20 800	8·9 19 900	8·5 19 100			
1Cr–½Mo	15·0	26·7–40·0	17	4t	14·5 32 400	14·0 31 300	13·5 30 200	12·1 27 100	10·6 23 800	9·6 21 500	9·4 21 100	9·2 20 600	9·0 20 200		
2¼Cr–1Mo (Note 1)	15·0	26·7–36·2	20	4t	12·7 28 400	11·5 25 800	9·9 22 200	9·6 21 500	9·3 20 800	8·9 19 900	8·6 19 200	8·4 18 800	8·1 18 200	7·8 17 500	
2¼Cr–1Mo (Note 2)	17·0	31·7–44·4	16	4t	16·4 36 700	16·2 36 300	15·9 35 600	15·2 34 000	14·6 32 700	14·0 31 300	13·3 29 700	12·7 28 400	12·1 27 000		
½Cr–½Mo–¼V	19·0	29·8–39·4	20	4t	16·4 36 700	16·2 36 300	15·9 35 600	15·2 34 000	14·6 32 700	14·0 31 300	13·2 29 700	12·7 28 400	12·1 27 000		
17–13–Mo	12·0	33·0–45·1	30	3t											
18–12–Nb	13·5	33·0–45·1	30	3t											
18–10–Ti	11·0	33·0–45·1	30	3t											

t = thickness of bend test piece.

NOTES: 1. Annealed condition.
2. Normalised and tempered condition.

TABLE Q 7.4

Mechanical Properties of Tubes and Pipes Category II

Grade of Steel	Yield Stress Minimum kg/mm²	Tensile Strength kg/mm²	Elongation on $5{,}65\sqrt{So}$ % Minimum	Bend Test Maximum diameter of former	Lower Yield Stress or 0,2 % Proof Stress, kg/mm² (Note 1)										
					100°C	150°C	200°C	250°C	300°C	350°C	400°C	450°C	500°C	550°C	600°C
Carbon	16,5	33–45	27	3t	12,6	12,1	11,7	10,7	9,2	7,3	7,2	7,1			
	17,8	35–47	27	3t	13,6	13,3	13,0	11,7	10,2	8,4	8,2	8,2			
	21,5	42–54	23	4t	18,0	17,6	17,3	15,8	14,2	12,6	12,3	12,0			
1Cr–$\frac{1}{2}$Mo	22,5	42–63	17	4t	19,5	18,7	18,1	16,2	14,2	12,8	12,6	12,3	12,1		
$2\frac{1}{4}$Cr–1Mo (Note 2)	21,5	42–57	20	4t	17,0	15,4	13,3	12,8	12,4	11,9	11,5	11,2	10,9	10,4	
$2\frac{1}{4}$Cr–1Mo (Note 3)	25,0	50–70	16	4t	21,9	21,7	21,3	20,4	19,5	18,7	17,7	17,0	16,1		
$\frac{1}{2}$Cr–$\frac{1}{2}$Mo–$\frac{1}{4}$V	28,0	47–62	20	4t	21,9	21,7	21,3	20,4	19,5	18,7	17,7	17,0	16,1		
17–13–Mo	19,0	52–71	30	3t											
18–12–Nb	21,0	52–71	30	3t											
18–10–Ti	17,0	52–71	30	3t											

t = thickness of bend test piece.

NOTES: 1. The values for lower yield stress or 0,2 per cent proof stress at elevated temperatures are given for design purposes and do not have to be proved by tests.

2. Annealed condition.

3. Normalised and tempered condition.

or in British units:—

TABLE Q 7.4

Mechanical Properties of Tubes and Pipes Category II

Grade of Steel	Yield Stress Minimum ton/in²	Tensile Strength ton/in²	Elongation on $5\cdot65\sqrt{S_0}$ % Minimum	Bend Test Maximum diameter of former	Lower Yield Stress or 0·2 % Proof Stress, lb/in² (Note 1)										
					100°C	150°C	200°C	250°C	300°C	350°C	400°C	450°C	500°C	550°C	600°C
Carbon	10·5	21·0–28·6	27	3t	17 900	17 200	16 600	15 200	13 100	10 400	10 200	10 100			
	11·3	22·2–29·8	27	3t	19 300	18 900	18 500	16 600	14 500	11 900	11 700	11 700			
	13·7	26·7–34·3	23	4t	25 600	25 000	24 600	22 500	20 200	17 900	17 500	17 100			
1Cr–½Mo	14·3	26·7–40·0	17	4t	27 700	26 600	25 700	23 000	20 200	18 200	17 900	17 500	17 200		
2¼Cr–1Mo (Note 2)	13·7	26·7–36·2	20	4t	24 200	21 900	18 900	18 200	17 600	16 900	16 400	15 900	15 500	14 800	
2¼Cr–1Mo (Note 3)	15·9	31·7–44·4	16	4t	31 100	30 900	30 300	29 000	27 700	26 600	25 200	24 200	22 900		
½Cr–½Mo–¼V	17·8	29·8–39·4	20	4t	31 100	30 900	30 300	29 000	27 700	26 600	25 200	24 200	22 900		
17–13–Mo	12·0	33·0–45·1	30	3t											
18–12–Nb	13·5	33·0–45·1	30	3t											
18–10–Ti	11·0	33·0–45·1	30	3t											

t=thickness of bend test piece.

NOTES: 1. The values for lower yield stress or 0·2 per cent proof stress at elevated temperatures are given for design purposes and do not have to be proved by tests.

2. Annealed condition.

3. Normalised and tempered condition.

TABLE Q 7.5

Average Values for Stress to Rupture in 100 000 hrs. Units kg/mm^2

Temp. °C	Carbon Steel	Alloy Steels					
		1Cr–½Mo	2¼Cr–1Mo	½Cr–½Mo–¼V	17–13–Mo	18–12–Nb	18–10–Ti
350	21,5						
360	19,7						
370	17,9						
380	16,0						
390	14,3						
400	12,5						
410	10,8						
420	9,4						
430	8,3						
440	7,3						
450	6,5	32,0		33,1			
460	5,7	28,4		29,9			
470	5,0	25,0		26,9			
480	4,4	21,6	21,4	24,1			
490	3,8	18,3	19,2	21,4			
500	3,3	15,1	17,2	18,9			
510		12,4	15,1	16,5			
520		10,1	13,2	14,2			
530		8,0	11,5	12,1			
540		6,3	9,9	10,2			
550		5,0	8,5	8,8	20,8	16,1	19,5
560		4,1	7,2	7,4	19,2	14,6	18,1
570		3,2	6,1	6,5	17,6	13,2	16,8
580		2,4	5,2	5,5	16,1	11,8	15,6
590			4,4		14,5	10,5	14,3
600			3,8		13,1	9,3	13,1
610					11,5	8,2	11,8
620					10,4	7,2	10,5
630					9,1	6,3	9,3
640					8,0	5,5	8,2
650					7,1	4,7	7,2
660					6,0	4,1	6,1
670					5,3	3,5	5,2
680					4,6	3,0	
690						2,5	
700						2,0	
710						1,7	
720							

or in British units:—

TABLE Q 7.5

Average Values for Stress to Rupture in 100 000 hrs. Units lb/in²

Temp. °C	Carbon Steel	Alloy Steels					
		1Cr–½Mo	2¼Cr–1Mo	½Cr–½Mo–¼V	17–13–Mo	18–12–Nb	18–10–Ti
350	30 600						
360	28 000						
370	25 400						
380	22 800						
390	20 300						
400	17 800						
410	15 300						
420	13 400						
430	11 800						
440	10 400						
450	9200	45 500		47 000			
460	8000	40 400		42 500			
470	7100	35 600		38 300			
480	6200	30 700	30 500	34 300			
490	5400	26 000	27 300	30 400			
500	4700	21 500	24 400	26 900			
510		17 600	21 500	23 500			
520		14 400	18 800	20 200			
530		11 400	16 400	17 200			
540		9000	14 100	14 500			
550		7100	12 100	12 500	29 600	22 800	27 800
560		5800	10 300	10 500	27 300	20 800	25 800
570		4600	8700	9200	25 100	18 800	24 000
580		3400	7400	7800	22 800	16 800	22 200
590			6300		20 600	15 000	20 400
600			5400		18 600	13 200	18 600
610					16 600	11 600	16 800
620					14 800	10 300	15 000
630					13 000	9000	13 200
640					11 400	7800	11 600
650					10 100	6700	10 300
660					8700	5800	8700
670					7600	4900	7400
680					6500	4300	
690						3600	
700						2900	
710						2500	
720							

Section 8

CAST IRON CRANK SHAFTS

General

801 Cast iron crank shafts are to be cast at an approved foundry to an approved material specification, and to approved manufacturing and inspection procedures. The inspection procedure will include the approved size, form and location of the test blocks on the crank shaft castings.

Grades of Cast Iron

802 Any suitable grade of flake graphite, low alloy, acicular or spheroidal or nodular graphite cast iron may be used for crank shafts. The minimum tensile strength of the particular grade of cast iron, corresponding to the section of the crank shaft, is not to be less than that detailed in the approved Specification. (*See* H 202, also N 330 and N 331).

Process of Manufacture

803 The raw materials of a charge such as pig iron, return scrap and scrap steel, are to be specially selected. The melt is to be closely controlled particularly with regard to temperature, time and composition when inoculated irons are being produced. Where such irons are made, the casting temperature and the time between completion of the inoculation and finished pouring of the castings are to be recorded. The records are to be available to the Surveyor at any time.

The Surveyor is to be provided with a statement giving the chemical composition of the material used for each crank shaft or batch of crank shafts.

Heat Treatment

804 In general, crank shaft castings other than those which are fully annealed, normalised or oil quenched and tempered, are to receive a suitable stress relief heat treatment before machining.

805 All heat treatments of castings are to be carried out in properly constructed furnaces which are efficiently maintained and have adequate means of temperature control of the furnace charge. Each casting is to be slowly and uniformly heated to the necessary temperature.

806 Unless otherwise agreed, test blocks are not to be removed from castings until all heat treatments have been completed. Test blocks are to receive the same heat treatment as the castings and are to be removed from castings and cut to provide test pieces by methods which do not impair or modify the characteristics of the materials. Flame cutting is not permitted for the removal of test blocks from a casting or for cutting up test blocks to provide test pieces.

Provision of Test Material

807 Unless otherwise approved, test material is to be provided by test blocks cast integral with or gated from each crank shaft. The test blocks are to be sufficient in number to allow of retests, if required. The dimensions of test blocks are to be such as to ensure that the material properties are similar to those of the average section of the crank shaft casting.

Dimensions of Test Pieces

808 The diameter of a tensile test piece is to be as large as practicable. In general, it should not be less than 14 mm (0·564 in) diameter.

A small flat is to be ground on each crank shaft casting and the Brinell hardness determined.

Number of Tests

809 At least one tensile test piece is to be taken for each crank shaft.

Testing Machines

810 Tensile tests are to be carried out by competent personnel in an approved machine of adequate capacity. The machine is to be maintained in an efficient and accurate condition and is to be checked and calibrated at suitable intervals agreed by the Society.

Mechanical Properties

811 The results of the tensile and hardness tests are to comply with the approved specification for the material.

Additional Tests Before Rejection

812 Where the results of a tensile test do not comply with the specification, two retests are permitted. If the

results of both retests are satisfactory the casting is acceptable as regards the tensile test. If either of the retests fails the casting is unacceptable. For castings which were fully heat treated, reheat treatment followed by retesting may be permitted provided the size of the residue of the test block(s) is suitable, and the agreement of the Surveyor is obtained.

Batch Testing

813 In the case of small shafts which are produced in quantity and are heat treated together, a system of batch testing may be adopted with the agreement of the Surveyor. In these cases, however, not less than two test pieces are required per melt of which one is to represent the first shaft to be cast and the other the last shaft to be cast.

Inspection of Castings

814 Where surplus material is tc be removed from crank shaft castings before despatch, a machining method is to be employed. Flame cutting is not permissible.

Finished castings which have passed test are to be examined by the Surveyor before despatch. The castings are to be in a clean condition so that all surfaces may be examined including those of bores. Castings are to be free from cracks and other detrimental defects. Cast iron crank shafts are not to be repaired by welding and blemishes are not to be plugged with a filler.

Branding

815 Every casting, after it has withstood satisfactorily the prescribed tests and inspection, is to be clearly marked by the Surveyor indicating that the casting has complied with the requirements of the Society.

In the event of any casting proving unsound during machining or at any subsequent stage of survey, it is to be rejected notwithstanding any previous certificate of satisfactory test and inspection.

Surface Treatment

816 Where it is proposed to harden the surfaces of machined pins and/or journals of cast iron crank shafts, details of the process are to be submitted for approval. Before such a process is applied to a crank shaft it is to be demonstrated by procedure tests and to the satisfaction of the Surveyor, that the process is suitably controlled and does not impair the strength or soundness of the material.

Section 9

COPPER ALLOY PROPELLERS AND PROPELLER BLADES

General

901 The requirements of this Section are applicable to propeller castings of the following non-ferrous materials:—

(a) Manganese bronze or high tensile brass with a minimum tensile strength of 44 kg/mm^2 (28 ton/in^2).

(b) High tensile aluminium bronzes with a minimum tensile strength of 63 kg/mm^2 (40 ton/in^2).

Particulars of chemical composition and mechanical properties of proprietary alloys are to be submitted for information.

902 Where it is proposed to use other non-ferrous materials or different grades of type (a) and (b) alloys, full particulars are to be submitted for consideration.

903 Castings are to be clean and free from harmful defects and are to be tested and inspected at the makers' works. In the event of any casting proving defective in the course of subsequent machining such casting may be rejected notwithstanding any previous certification of satisfactory test.

Provision of Test Samples

904 Test samples, sufficient for the preparation of at least three test pieces, are to be provided for each casting. The test samples are to be of approved form and may be separately-cast or integral with the casting.

905 Separately-cast test samples:— These may be adopted at works where Surveyors are in frequent attendance. The procedure for identifying the test samples and the propeller casting is to be approved by the Surveyors who in cases of doubt may require that check analyses of sample and casting be made.

The samples are to be separately cast at the same time and from the same metal as the casting which they represent, and are to be poured into moulds of the same material as that used for the casting. Where a casting is made from more than one ladle test samples are to be provided for each ladle.

906 Integral test samples:— These are to be provided as blocks on the surfaces of the casting. Samples gated from the casting are not acceptable.

NOTE.—With the object of obtaining sound test blocks and of permitting free contraction of the propeller casting, it is preferable that the test blocks be arranged axially on the hub instead of on the blades at mid-radii.

Mechanical Properties

907 Test pieces are to be 14 mm (0·564 in) diameter with a gauge length of 50 mm (2 in) or of other similar standard. At least one tensile test is to be made for each casting and for each ladle if 905 is applicable. The test results are to comply with the requirements of Table Q 9.1 or of a specification specially approved.

If the first test piece fails to meet requirements, then the two remaining test pieces are to be broken; if these also fail the casting is to be rejected.

TABLE Q 9.1

Material	Minimum Tensile Strength kg/mm^2 (ton/in^2)		Minimum Elongation per cent on 50 mm (2 in) gauge length
	Integral test piece	Separately-cast test piece	
(a) Manganese Bronze	44(28)	47(30)	20
(b) Aluminium Bronze	63(40)	66(42)	15

NOTE.—The values in the table are applicable to test pieces and are not necessarily obtainable from all parts of the castings. In general it can be expected that the mechanical properties of a propeller, especially in the thick root sections of the blades, will be inferior to those of the test piece.

23rd July, 1970

APPENDIX

STEEL MANUFACTURERS

The following establishments have complied with the requirements for quality and testing of steel and have been recognised by the Committee.

Firms in Great Britain and Ireland

Allied Ironfounders, Ltd., Larkhall Steel Foundry, Larkhall, Lanarkshire. (*Castings*)
Alston Foundry Co., Ltd., Nent Force Foundry, Alston, Cumberland. (*Small castings*)
Andrews Toledo, Ltd., Toledo Steel Works, Neepsend, Sheffield. (*Ingots and billets*)
Baird, Archibald, & Sons, Ltd., Hamilton, Lanarkshire. (*Castings*)
Baker, W. A., & Co., Ltd., Westgate Works, Newport, Mon. (*Castings*)
Baker Perkins, Ltd., Peterborough. (*Small castings*)
Beardmore, William, & Co., Ltd., Parkhead, Glasgow. (*Castings, forgings, billets and blooms*)
Blackett, Hutton & Co., Ltd., Cleveland Steel Foundry, Guisborough, Yorkshire. (*Castings*)
Blair, George, & Co., Ltd., Armond Carr Works, Tow Law, Co. Durham. (*Castings*)
Blair, George & Co., Ltd., Newcastle Alloy Steel Foundry, Newcastle upon Tyne. (*Small castings*)
Bond's Foundry Co., Ltd., Tow Law, Co. Durham. (*Small castings*)
Bonnington Castings, Ltd., Leith. (*Castings*)
British Rolling Mills, Ltd., Brymill Works, Tipton, Staffs. (*Cold drawn bright bars*)

British Steel Corporation.

General Steels Division. Divisional Headquarters—Glasgow
Divisional Office (Teesside)—Middlesbrough

Works:—

Appleby-Frodingham, Scunthorpe, Lincs. (*Slabs, blooms, billets, plates, sections, bars and rods*)
Barrow, Barrow-in-Furness, Lancashire. (*Billets, bars and sections*)
Cargo Fleet, Middlesbrough. (*Sections and bars*)
Consett, Blackhill, Durham. (*Plates*)
Clydebridge, Cambuslang, near Glasgow. (*Plates*)
Dalzell, Motherwell, Lanarkshire. (*Plates, sections, bars and blooms*)
East Moors, Cardiff. (*Ingots, blooms, billets, sections and bars*)
Glengarnock, Glengarnock, Ayrshire. (*Sections and bars*)
Hartlepool, Hartlepool, Co. Durham. (*Plates*)
Irlam, Irlam, Lancashire. (*Billets, bars and sections*)
Lanarkshire, Motherwell, Lanarkshire. (*Sections*)
Monks Hall and Co., Warrington. (*Rolling mill for bars*)
Normanby Park, Scunthorpe, Lincs. (*Ingots, billets, slabs and bars*)
Redbourn, Scunthorpe, Lincs. (*Ingots, billets, bars and slabs*)
Wm. Robertson, Talbot Stead & Co., Latchford, Warrington. (*Cold drawn bright bars*)
Skelton, Stoke on Trent. (*Ingots, billets, bars and sections*)
Skinningrove, Saltburn-by-the-Sea. (*Sections and bars*)
South Teesside, Middlesbrough.

Britannia. (*Rolling mills for sections and bars*)
Cleveland. (*Sections and bars*)
Lackenby. (*Ingots, billets, sections, bars, strips and plates*)
Redcar. (*Ingots*)

Victoria, Coatbridge, Lanarkshire. (*Sections and bars*)

Warrington, Warrington, Lancs. *(Rolling mills for sections and bars)*
Workington, Workington, Cumberland. *(Ingots, blooms, billets, slabs and bars for manufacture of small forgings (Acid Bessemer or electric steel), rolled sections (electric steel only))*

Strip Mills Division. Divisional Headquarters—Cardiff.
Works:—
Ebbw Vale, Ebbw Vale, Mon. *(Ingots)*
Jarrow, Jarrow-on-Tyne. *(Rolling mills for sections and rounds)*
Lancashire and Corby, Corby, Northants. *(Ingots, billets, slabs and strips)*
Llanwern, Newport, Mon. *(Light plates)*
Port Talbot, Glam. *(Ingots, plates and strips)*
Ravenscraig, Ravenscraig, Lanarkshire. *(Ingots, rolled slabs and thin plates)*
Shotton, Shotton, Flints. *(Ingots, slabs and light plates)*
Whitehead, Newport, Mon. *(Rolling mill for strips, bars and sections)*

Special Steels Division. Divisional Headquarters—Sheffield.
Works:—
Bilston, Staffordshire. *(Tube ingots, billets and bars)*
Brymbo, Wrexham, Denbighshire. *(Electric steel for forgings and re-rolling)*
Craigneuk, Motherwell. *(Castings, forgings, billets and bars)*
Grimesthorpe, Sheffield. *(Ingots and castings)*
Hallside, Glasgow. *(Castings and billets)*
Openshaw, Manchester. *(Forgings, bars, plates up to ½ inch in thickness)*
Park Gate, Rotherham. *(Ingots, billets, bars, sections and strips)*
River Don, Sheffield. *(Ingots, forgings, plates and billets)*
Steel Peech and Tozer, Rotherham. *(Ingots, blooms, bars and forgings)*
Stocksbridge, Sheffield. *(Ingots, blooms, billets, slabs and plates)*
Taylor Bros, Manchester. *(Ingots)*
Tinsley Park, Sheffield. *(Ingots, blooms, billets, slabs and bars)*
Toll Cross, Glasgow. *(Castings)*

Tubes Division. Divisional Headquarters—Corby, Northants.
Works:—
Clydesdale, Bellshill, Lanarkshire. *(Ingots, billets, slabs and strips for tubes)*

Briton Ferry Steel Co., Ltd., Briton Ferry, Neath, Glamorgan. *(Billets)*
Broadbent, H., & Son Ltd., Foundry Division of Dewrance Triangle Ltd., Ashton-under-Lyne. *(Small castings)*
Brockhouse Castings, Ltd., Wednesfield, Wolverhampton. *(Small castings)*
Brown Bayley Steels, Ltd., Sheffield. *(Ingots, forgings and bars)*
Brown, The David, Gear Industries, Ltd., (Foundry Division), Penistone, Yorks. *(Castings)*
Brown, Lenox & Co., Ltd., Pontypridd. *(Castings)*
Cameron Iron Works, Livingston, West Lothian. *(Forgings)*
Catton & Co., Ltd.,
Yorkshire Steel Foundry, 29, Chadwick Street, Hunslet, Leeds. *(Castings)*
Pontefract Lane, Leeds. *(Small castings)*
Coghlan Forge & Rolling Mills, Ltd., and Coghlan Bright Steel, Ltd., Hunslet Forge, Leeds. *(Rolling mills for bars)*
Crofts (Engineers), Ltd., Thornbury, Bradford. *(Castings)*
Cruikshank & Co., Ltd., Denny Iron Works, Denny, Stirlingshire. *(Small castings)*
Darwins Ltd., Tinsley, Sheffield. *(Ingots and forgings)*
Davy & United Roll Foundry, Ltd., Empire Works, Haverton Hill, Billingham, Co. Durham. *(Castings)*
Doxford & Sunderland Shipbuilding & Engineering Co., Ltd., Wolsingham Steelworks, Wolsingham, Bishop Auckland, Co. Durham. *(Ingots and castings)*
Dunford Hadfields, Ltd., East Hecla Works, Sheffield. *(Ingots, blooms, billets, forgings, bars, special sections and castings)*
Edgar Allen Foundry, Ltd., Imperial Steel Works, Tinsley, Sheffield 9. *(Castings)*

Firth Brown, Ltd.,
- Atlas Works, Sheffield. (*Ingots, forgings, rolled bars and billets*)
- Scunthorpe Works, Scunthorpe, Lincs. (*Castings*)

Firth Vickers Stainless Steels, Ltd.,
- Sheffield Works, Sheffield. (*Rolling mills for plates, bars and sections; also castings*)
- Staybrite Works, Halesowen, Worcs. (*Castings*)

Glanmorfa, Ltd., Llanelly. (*Castings and ingots*)

Guest, Keen & Nettlefolds (South Wales), Ltd., Cardiff.
- Castle Works. (*Rolling mills for bars and strips*)
- Tremorfa Works. (*Rolling mills for bars and sections*)

Halesowen Steel Co., Ltd., The, Halesowen, near Birmingham. (*Cold drawn bright bars*)

Hamilton, A., & Sons Ltd., Victoria Foundry, East Moors, Cardiff. (*Small castings*)

Head, Wrightson Steel Foundries, Ltd.,
- Light Pipe Hall Road, Stockton-on-Tees. (*Castings*)
- Teesdale Iron Works, Thornaby-on-Tees. (*Castings*)

Hopkinsons, Ltd., Britannia Works, Huddersfield, Yorkshire. (*Castings*)

Hyde, Robert & Son, Ltd.,
- Clarendon Works, Chesterfield. (*Small castings*)
- North Stafford Steel Foundry, Stoke-on-Trent. (*Small castings*)

James Mills (Bredbury), Ltd., Bredbury Steel Works, Bredbury, Nr. Stockport. (*Rolling mills for bars*)

Jessop-Saville, Ltd., Brightside Works, Sheffield. (*Ingots, blooms, bars and forgings*)

Jopling, E., & Sons, Ltd., Pallion, Sunderland. (*Castings*)

K. & L. Steelfounders & Engineers Limited, Letchworth, Hertfordshire. (*Castings*)

Kirkstall Forge Engineering, Ltd., Leeds. (*Forgings*)

Lake & Elliot, Ltd., Engineers and Founders, Braintree, Essex. (*Small castings*)

Lilleshall Co., Ltd., St. George's, near Oakengates, Shropshire. (*Rolling mills for sections and bars*)

Llanelly Steel Co. Ltd., Llanelly Steel Works, Llanelly. (*Billets and bars*)

Lloyd, F. H., & Co., Ltd.,
- James Bridge, near Wednesbury, Staffordshire. (*Ingots and castings*)
- Cardiff Works, Curran Road, Cardiff. (*Ingots and castings*)

Lloyds (Burton) Ltd., Wellington Works, Burton upon Trent, Derbyshire. (*Ingots and castings*)

Lloyds (Darlington) Ltd., Darlington. (*Small castings*)

Martins (Dundyvan), Ltd., Coatbridge, Lanarkshire. (*Rolling mills for sections*)

National Steel Foundry (1914), Ltd., The, Kirkland Works, Leven, Fifeshire. (*Castings*)

North British Steel Group Ltd., Bathgate Road, West Lothian.
- Armadale Works, (*Castings*)
- Bathgate Works, (*Castings*)

Osborn Hadfield Steel Founders, Ltd., Clyde Steel Works, Sheffield. (*Castings*)

Parker Foundry Ltd., Mansfield Road, Derby. (*Small castings*)

Patent Shaft Steel Works, Ltd., Wednesbury, Staffordshire.

Porterfield Foundries Ltd., Renfrew. (*Castings*)

Raine & Co., Ltd., Delta Iron & Steel Works, Derwenthaugh, Newcastle upon Tyne. (*Rolling mills for sections and bars*)

Redheugh Iron & Steel Co. (1936), Ltd., Teams, Gateshead-on-Tyne. (*Rolling mills*)

Renton & Fisher, Ltd., Hopetoun Steel Works, Bathgate. (*Castings*)

Round Oak Steel Works, Ltd., Brierley Hill, Staffordshire. (*Ingots, blooms, billets, bars and sections*)

Royal Ordnance Factory, Patricroft, Manchester. (*Ingots*)

Ryder Brothers, Ltd. (Beehive Steel Foundry), Bolton. (*Castings*)

Shaw, W., & Co., Ltd., Wellington Cast Steel Foundry, Middlesbrough. (*Castings*)

Spartan Steel and Alloys Ltd., Spartan Works, Birmingham 6. (*Ingots*)

Spear & Jackson, Ltd., Sheffield. (*Ingots and billets*)
Vickers Ltd., Shipbuilding Group, Barrow Engineering Works, Barrow-in-Furness. (*Forgings*)
Williams, John, (Wishaw), Ltd., Excelsior Iron & Steel Works, Wishaw, Lanarkshire. (***Rolling mills for thin plates***)
Wilson's Foundry & Engineering Co., Ltd., Bishop Auckland, Co. Durham. (*Castings*)

Irish Republic.

Irish Steel Holdings Ltd., Haulbowline, Co. Cork. (*Ingots, bars and sections*)

Firms in Countries other than Great Britain and Ireland (alphabetically arranged)

Note: The place of residence of the Surveyor giving attendance at each works is shown in parentheses.

A.1. Iron & Steel Foundry, Ltd., Vancouver, B.C. (*Small castings*) (Vancouver)

A.G. Der Dillinger Huttenwerke, Dillingen/Saar, Germany. (*Ingots and plates*) (Saarbrucken)

A.S.S.A. Acciaierie di Susa Società Anonima, Turin, Italy. *Head Office:* Turin. *Works:* Susa. (*Castings*) (Genoa)

Aceria Bragado S.A.I.C., Bragado, Argentina. (*Castings*) (Buenos Aires)

Acerias y Forjas de Azciotia, Azciotia Juipuzcoa, Spain. (*Ingots and small rolled bars*) (Bilbao)

Aceros de Galicia, Vigo Spain. (*Castings*) (Vigo)

Aceros y Fundiciones del Norte Pedro Orbegozo y Cia., S.A., Hernani, (Guipuzcoa), Spain. (*Ingots, forgings and rolled bars*) (Bilbao)

Aciéries du Furan, St. Etienne (Loire), France. (*Electric steel castings*) (Paris)

Aciéries & Fonderies de l'Est, France.
- Usine de Colombier-Fontaine. (*Small Castings*) (Paris)
- Usine de Sainte-Suzanne. (*Small Electric Castings*) (Paris)

Acos Villares S.A. Sao Caetano do Sul, Sao Paulo, Brazil. (*Castings, forgings, billets and bars*) (Sao Paulo)

Agrometal S.A., Miranda de Ebro Works, Bilbao, Spain. (*Castings*) (Bilbao)

Ahlström, A., Oy, Osakeyhtio Karhulan Tehtaat, Karhula Bruk, Karhula, Finland. (*Castings*) (Helsinki Helsingfors)

Aichi Steel Works, Ltd.
- Chita Plant, Aichi Prefecture, Japan. (*Ingots and bars*) (Kobe)
- Kariya Plant, Aichi Prefecture, Japan. (*Ingots and bars*) (Kobe)

Aktiebolaget Jarnforadling, Halleforsnas, Sweden. (*Small castings*) (Stockholm)

Algoma Steel Corporation, Ltd., Sault St. Marie, Ontario, Canada. (*Plates, sections and bars*) (Toronto)

Allard, Usines & Aciéries, Société Anonyme, Mont-sur-Marchienne, near Charleroi, Belgium. (*Castings*) (Antwerp)

Allard, Usines & Aciéries, Société Anonyme, Turnhout, Belgium. (*Small castings*) (Antwerp)

Altos Hornos de Mexico, S.A., (A.H.M.S.A.), Monclova, Coah., Mexico. (*Plates*) (Mexico City)

American Rolling Mill Co., Middletown, O., U.S.A. (*Castings and forgings*) (Cleveland, O.)

Åminnefors Kb, Ky, Åminnefors Stalverk, Åminnefors, Finland. (*Ingots, billets, bars and sections*) (Åbo)

Amsco Italiana S.p.A., Milan, Italy. (*Small castings*) (Milan)

Amurrio, S.A., Talleres de., Amurrio, Alava, Spain. (*Steel castings*) (Bilbao)

Anderson, Aktiebolaget Abjörn, Svedala, near Malmö, Sweden. (*Castings*) (Malmö)

Ando Iron Works Co., Ltd., Tokyo, Japan. (*Small forgings*) (Yokohama)

Ansaldo Meccanico Nucleare S.p.A., Stabilimento Fonderia di Ghisa e Metalli, Genova-Pegli, Italy. (*Forgings*) (Genoa)

ARANZABAL S.A., Victoria, Alava, Spain. (*Small castings*) (Bilbao)

"A R B E D", Aciéries Réunies de Burbach-Eich-Dudelange,
- Division de Belval, Esch-sur-Allzette, Luxembourg. (*Ingots, blooms, billets, bars, angle bars, and sections*) (Saarbrücken)
- Division de Differdange, Differdange, Luxembourg. (*Sections and bars*) (Saarbrücken)
- Division de Dommeldange, Dommeldange, Luxembourg. (*Ingots, forgings and castings*) (Saarbrücken)
- Division d'Esch, Esch-sur-Allzette, Luxembourg. (*Ingots, bars and sections*) (Saarbrücken)
- Division de Burbach, Sarrebruck,
  - Burbach Works. (*Ingots, billets and sections*) (Saarbrücken-Saar)
  - Hostenbach Works. (*Plates*) (Saarbrücken-Saar)

Asano Tekkosho Co., Ltd., Saijo-Shi, Shikoku, Japan. (*Small forgings*) (Kobe)

Astilleros de Cadiz S.A., Factoria de Manises, Valencia, Spain. (*Castings and forgings*) (Valencia)

Astilleros Rio Santiago Ensenada, Buenos Aires, Argentina. (*Steel castings*) (Buenos Aires)

Astilleros y Talleres del Noroeste S.A., El Ferrol del Caudillo, Spain. (*Small forgings and small castings*) (El Ferrol)

Ateliers du Creusot, Société des Forges et, Usines Schneider, Usine de Pamiers, Pamiers, France. (*Castings and forgings*) (Marseilles)

Atlantic Steel Castings Co., The, Chester, Pa., U.S.A. (*Castings*) (Philadelphia)

Atlas Steels Company, Welland, Ontario, Canada. (*Ingots and bars*) (Toronto)

Aubert et Duval, Anciens Ets., Aciéries des Ancizes, Puy de Dome, France. (*Ingots, rolled bars and forgings*) (Paris)

August Thyssen - Hutte A.G., Duisburg - Hamborn, Germany.
- Area Hamborn. Steelworks Beeckerwerth, Bruckhausen and Ruhrort. (*Ingots, billets, slabs, plates and sections*) (Dusseldorf)
- Area Mülheim. Steelworks Mülheim (*Ingots, slabs and plates*) (Dusseldorf)
- Duisburg-Huttenheim. (*Plates*) (Dusseldorf)

Australian Iron & Steel, Pty., Ltd.,
Port Kembla, N.S.W. (*Plates, bars, sections and forgings*) (PORT KEMBLA)
Steelworks, Kwinana, Western Australia. (*Small bars and sections*) (FREMANTLE)

d'Auxonne, Acieries & Fonderies, Auxonne (Côte d'Or), France. (*Small castings*) (PARIS)

Avesta Jernverks Aktiebolag, Avesta, Sweden. (*Plates, sections and castings*) (STOCKHOLM)

Azuma Steel Casting Co. Ltd., Takaoka Works, Takaoka, Japan. (*Castings*) (YOKOHAMA)

Azuma Steel Works, Ltd.
Azuma Plant, Tokyo, Japan. (*Ingots for plate*) (YOKOHAMA)
Senju Plant, Tokyo, Japan. (*Rolling mills for plates*) (YOKOHAMA)

Babcock & Wilcox, Sociedad Espanola de Construcciones.
Head Office: Calle Ercilla 1, Bilbao, Spain.
Works: Galindo-San Salvador Del Valle, Vizcaya, Spain. (*Castings, ingots and forgings*) (BILBAO)

Bakker, N.V., Machinefabriek-Staalgieterij, Ridderkerk, Holland. (*Ingots and castings*) (ROTTERDAM)

Basconia, Compañia Anonima, Bilbao, Spain. (*Plates, sections and bars*) (BILBAO)

Bergische Stahlindustrie K.G., Remscheid, Germany. (*Castings*) (DUSSELDORF)

Bertoli S.p.A., Officine Fratelli Bertoli fu Rodolfo, Udine, Italy. (*Castings, forgings, bars and sections*) (TRIESTE.)

Bethlehem Steel Corporation,
Bethlehem, Pa., U.S.A. (*Ingots, forgings, bars and sections*) (PHILADELPHIA)
Burns Harbour Plant, Chesterton, Indiana, U.S.A. (*Rolling mills for plates*) (CHICAGO)
Johnstown Plant, Johnstown, Pa., U.S.A. (*Ingots, billets, slabs, plates and bars*) (CLEVELAND)
Lackawanna, N.Y., U.S.A. (*Ingots, blooms, billets, bars, plates and sections*) (CLEVELAND, O.)
Lebanon, Pa., U.S.A. (*Rolling mills for bars and rivets*) (PHILADELPHIA)
Los Angeles 54, Cal., U.S.A. (*Round bars*) (LOS ANGELES)
Seattle, Wash., U.S.A. (*Sections and bars*) (SEATTLE)
Sparrows Point, Md., U.S.A. (*Plates*) (BALTIMORE)
Steelton, Pa., U.S.A. (*Castings*) (PHILADELPHIA)

Bhartia Electric Steel Co., Ltd., Calcutta, India. (*Castings*) (CALCUTTA)

Birdsboro Corporation, Birdsboro, Pa., U.S.A. (*Castings*) (PHILADELPHIA)

Björneborgs Jernverks Aktiebolag, Björneborg, Sweden. (*Ingots and forgings*) (GOTHENBURG)

Black Clawson-Kennedy, Owen Sound, Ontario, Canada. (*Castings*) (TORONTO)

Blanc-Misseron, Société Française des Aciéries de, Quievrechain, (Nord), France. (*Ingots and castings*) (VALENCIENNES)

Boel, Usines Gustave, Soc. An., La Louvière, Belgium. (*Ingots, forgings, castings, plates and universal flats*) (ANTWERP)

Bofors, Aktiebolaget, Bofors, Sweden. (*Ingots, forgings, castings and rolled bars*) (GOTHENBURG)

Böhler, Gebr. & Co., Aktiengesellschaft, Vienna, Austria.
Works: Bohlerwerk, Low Austria. (*Small forgings*) (VIENNA.)
Works: Bruckbach, Low Austria. (*Rolling mills for sections and bars*) (VIENNA)
Works: Kapfenberg, Styria. (*Ingots, castings, forgings, bars and plates*) (VIENNA)

Bolzano, S.p.A. Acciaierie di, Bolzano, Italy. (*Ingots, billets, bars and forgings*) (VENICE)

Boom, Travaux Métalliques de, Société Anonyme, Boom, Belgium. (*Small castings*) (ANTWERP)

Borsig A.G., Berlin-Tegel, Germany. (*Ingots, forgings and castings*) (BERLIN)

Boschgotthardshutte, Otto Breyer G.m.b.H., Edelstahlwerk-Press-u. Hammerwerk-Mechanische Werkstätten, Hüttental-Weidenau, Germany. (*Ingots and forgings*) (COLOGNE)

Boxholms A/B., Boxholm, Sweden. (*Ingots, rolled slabs, blooms, billets, sections and bars*) (STOCKHOLM)

Bradford Kendall Ltd.
Works: Adelaide, South Australia. (*Castings*) (ADELAIDE)
Works: Alexandria, Sydney, N.S.W. (*Castings*) (SYDNEY, N.S.W.)
Works: Runcorn, Queensland. (*Castings*) (BRISBANE.)

Brasileira de Usinas Metalurgicas, Companhia, Usina de Neves, Sao Goncalo, Estado do Rio de Janeiro, Brazil. (*Ingots, sections and bars*) (RIO DE JANEIRO)

Breda Fucine S.p.A., Sesto San Giovanni, Milan, Italy. (*Castings and forgings*) (MILAN)

Breda Siderurgica Società per Azioni, Sesto San Giovanni, Milan, Italy. (*Ingots and sections*) (MILAN)

Breitenbach, Ed., G.m.b.H., Huttental-Weidenau/Sieg, Germany. (*Castings*) (COLOGNE)

Bremer Vulkan, Schiffbau und Maschinenfabrik, Bremen-Vegesack, Germany. (*Castings*) (BREMEN)

Brescia, Acciaieria e Tubificio di, Società Anonima, Brescia, Italy. (*Ingots, sections and bars and castings*) (MILAN)

Broken Hill Proprietary Co., Ltd.
Iron & Steel Works, Newcastle, N.S.W. (*Ingots, billets, plates, sections, strip and castings*) (NEWCASTLE, N.S.W.)
Iron & Steel Works, Whyalla, S. Australia. (*Ingots, castings, bars and sections*) (WHYALLA)

Burlington Steel Company, Division of Slater Steel Industries, Ltd., Hamilton, Ontario, Canada. (*Small sections and bars*) (TORONTO)

Burmeister & Wain's Maskin-og Skibsbyggeri, Aktieselskabet, Copenhagen, Denmark. (*Ingots, forgings and castings*) (COPENHAGEN)

Burn & Co., Ltd., Howrah, India. (*Castings*) (CALCUTTA)

C.A.E. Machinery Ltd., Vancouver, B.C. (*Small castings*) (VANCOUVER)

Caleotto, Acciaieria e Ferriera del, S.p.A., Lecco, Italy. (*Ingots, castings, bars, small sections and small forgings*) (MILAN)

Canada Forging Ltd., Welland, Ontario, Canada. (*Forgings*) (TORONTO)

Canadian Steel Foundries Division Hawker Siddeley Canada Ltd., Longue Pointe, Montreal, P.Q., Canada. (*Castings*) (MONTREAL)

Canadian Unitcast-Steel, Ltd., Sherbrooke, P.Q., Canada. (*Castings*) (MONTREAL)

Cantieri Navali del Tirreno e Riuniti, S.p.A., Ancona, Italy. (*Small castings*) (VENICE)

Riva Trigoso, Genoa, Italy. (*Small Forgings*) (GENOA.)

Carlo Tassara, Stabilimenti Electtrosiderurgioi S.p.A., Breno, Brescia, Italy. (*Ingots and small forgings*) (MILAN)

Ceretti, Pietro Maria, S.p.A., Ferriera Dell'Ossola-Villadossola, Italy. (*Castings*) (MILAN)

Charleroi, Société Anonyme de la Fabrique de Fer de, Charleroi, Belgium. (*Ingots, slabs and plates*) (ANTWERP)

Cheoy Lee Shipyard Lantau Island, Hong Kong. (*Castings*) (HONG KONG)

Chiers, Société des Hauts-Forneaux de la, Forges de Vireux Molhain, Vireux, Ardennes, France. (*Bars and sections*) (VALENCIENNES)

Christiania Spigerverk, Oslo, Norway. (*Ingots and bars, also rivet bars*) (OSLO)

Chubu Steel Plate Co. Ltd., Nakagawa Works, Nagoya, Japan. (*Ingots and plates*) (KOBE)

Clabecq, Société Anonyme Forges de, Clabecq, Belgium. (*Ingots, plates, bars and sections*) (ANTWERP)

Cockerill-Ougrée-Providence S.A., Seraing, Belgium.

Group A Works: Division Centre, Ougrée. (*Ingots, blooms, billets, slabs and thin plates*) (ANTWERP)

Division Ouest, Seraing. (*Ingots, blooms, billets, slabs, castings and forgings*) (ANTWERP)

Group B Works: Marchienne-au-Pont. (*Sections, bars, ingots and blooms*) (ANTWERP)

Group D Works: d'Hautmont, Nord France. (*Ingots and sections*) (VALENCIENNES)

Colorado Fuel & Iron Corporation, Minnequa Works, Pueblo, Colorado, U.S.A. (*Ingots, bars and small sections*) (CHICAGO)

"COMETNA" Companhia Metalurgica Nacional, S.A.R.L., Amadora, Portugal. (*Castings*) (LISBON)

Commonwealth Steel Co., Ltd., Waratah, Newcastle, N.S.W. (*Castings, forgings, ingots and bars*) (NEWCASTLE, N.S.W.)

Compagnie des Ateliers et Forges de la Loire.

Usine des Dunes, Malo les Bains (Nord), France. (*Ingots, billets, blooms, bars and forgings*) (DUNKIRK)

Usines de l'Ondaine, Firmigny (Loire), France. (*Ingots, billets, blooms, bars, castings and forgings*) (PARIS)

Usines de St. Chamond, St. Chamond (Loire), France. (*Forgings*) (PARIS)

Usines de St. Etienne, St. Etienne (Loire), France. (*Plates*) (PARIS)

Compagnie Générale des Aciers, Société Anonyme, Thy-le-Château, Belgium. (*Castings*) (ANTWERP)

Companhia Ferro e Aco de Vitoria, Vitoria, State of Espirito Santo, Brazil. (*Rolling mill for bars and sections*) (RIO DE JANEIRO)

Companhia Siderurgica Nacional, Volta Redonda, Usina Presidente Vargas, Estado do Rio de Janeiro, Brazil. (*Plates and sections*) (RIO DE JANEIRO)

Companhia Siderurgica Paulista, Cosipa, Cubatao, Sao Paulo, Brazil. (*Ingots and plates*) (SANTOS)

Compañia Auxiliar de Ferrocarriles, Beasain, Guipuzcoa, Spain. (*Small castings and forgings*) (BILBAO)

Consolidated Mining & Smelting Co. of Canada Ltd., Trail, B.C., Canada. (*Castings*) (VANCOUVER)

Cooperativa Industrial Electrodos y Aceros, Boó., Santander, Spain. (*Castings*) (BILBAO)

Crane Fisa S.A., Bilbao, Spain. (*Small castings*) (BILBAO)

Creusot, Société des Forges et Ateliers du, (S.F.A.C.), Usines Schneider, Le Creusot, France. (*Ingots, forgings, castings, plates and sections*) (PARIS)

Crucible Steel Company of Canada, Ltd., Sorel, P.Q., Canada. (*Ingots and forgings*) (MONTREAL)

Crucible Steel Corporation, Midland Division, P.O. Box 226, Midland, Pa. 1505g., U.S.A. (*Ingots, slabs, billets, hot rolled and cold drawn bars*) (CLEVELAND, O.)

Daido Steel Co., Ltd.

Chita Plant, Nagoya, Aichi Prefecture, Japan. (*Ingots, billets and bars*) (KOBE)

Hoshizaki Plant, Nagoya, Japan. (*Ingots and bars*) (KOBE)

Shibukawa Works, Shibukawa, Japan. (*Ingots, small forgings and bars*) (YOKOHAMA)

Tsukiji Plant, Nagoya, Japan. (*Ingots, forgings and castings*) (KOBE)

Daitetsu Steel Industrial Co. Ltd., Osaka, Japan. (*Ingots and sections*)

Dalmine S.p.A. *Head Office:* Milan, Italy.

Dalmine Costa Volpino, Bergamo. (*Seamless tubes*) (MILAN)

Dalmine Works, Bergamo. (*Ingots and seamless tubes*) (MILAN)

Danske, (Det), Staalvalsevaerk A/S, Frederiksvaerk, Denmark. (*Plates, sections and bars*) (COPENHAGEN)

Date Seiko Co., Ltd., Tokyo, Japan. (*Castings*) (YOKOHAMA)

Davies & Baird Pty. Ltd., Newlands Road, Coburg, Melbourne, Australia. (*Castings*) (MELBOURNE)

De Wendel et Cie., S/A., Hayange, Moselle, France.
Usine de Fenderié. (*Plates*) (SAAR)
Usine de St. Jacques. (*Sections*) (SAAR)

Decker, Gebrüder, Betrieb 1, Eisen- & Stahlgiesserei, Nürnberg 2, Ostendstr. 84. (*Electric steel castings*) (AUGSBURG)

Dembiermont & Cie., Maurice, Hautmont (Nord), France. (*Forgings*) (VALENCIENNES)

Deusto, S.A., Talleres de, Luchana, Bilbao, Spain. (*Ingots, castings and small forgings*) (BILBAO)

Deutsche Edelstahlwerke A.G., Krefeld, Germany. (*Ingots, forgings and rolled materials*) (DUSSELDORF)

Dikkers, G., & Co., N.V., Hengelo, Holland. (*Small castings*) (AMSTERDAM)

Dingler, Karcher & Cie., G.m.b.H., Saarbrücken-Saar. (*Castings*) (SAARBRÜCKEN-SAAR)

Dingler, Karcher & Cie., G.m.b.H., Saarländisches Stahlwerk, Worms/Rhein, Germany. (*Castings*) (MANNHEIM)

Dominion Foundries & Steel Ltd., Hamilton, Ontario, Canada. (*Ingots, plates and castings*) (TORONTO)

Dominion Steel & Coal Corporation Ltd.
Montreal Works, 5870, St. Patrick Street, Montreal, Canada. (*Angles, bars and rivets*) (MONTREAL)

Donegal Steel Foundry Company, 601, East Market Street, Marietta, Pa., U.S.A. (*Castings*) (PHILADELPHIA)

Drammens Jernstoberi & Mek-Verksted, A/S, Drammen, Norway. (*Small castings*) (OSLO)

Dunswart Iron & Steel Works, Ltd., Benoni, South Africa. (*Castings, ingots, billets and small sections*) (VEREENIGING)

Duro-Felguera, Sociedad Metalúrgica, La Felguera, Asturias, Spain. (*Castings*) (GIJON)

Echevarria, Sociedad Anonima, Bilbao, Spain. (*Small sections and bars, small forgings and ingots*) (BILBAO)

Echeverria, Patricio, S.A., Legazpia, Spain. (*Ingots, blooms, forgings and small bars*) (BILBAO)

Edelstahlwerke Buderus A.G., Wetzlar, Germany. (*Ingots, blooms, billets, bars forgings and plates*) (COLOGNE)

Edelstahlwerk Witten A.G., Witten-Ruhr, Germany. (*Ingots, billets, bars, forgings and narrow flats*) (DORTMUND)

Edgewater Corporation, Oakmont, Pennsylvania, U.S.A. (*Ingots and forgings*) (CLEVELAND)

Eguiluz, Talleres, Miranda del Ebro, Burgos, Spain. (*Castings*) (BILBAO)

Egyptian Iron & Steel Co., S.A.E., Helwan, U.A.R. (*Plates*) (ALEXANDRIA)

Eisen-und Stahlwerk Pleissner G.m.b.H., Herzberg/Harz, Germany. (*Castings*) (HANNOVER)

Eisenwerk Bohmer, Witten, Ruhr, Dortmund, Germany. (*Castings*) (DORTMUND)

Eisenwerk Geweke, R. & C. R. Lange K.G., Hagen-Haspe, Germany. (*Electric steel castings*) (DORTMUND)

Eisenwerk Rödinghausen K.G., Lendringsen Krs., Iserlohn, Germany. (*Castings*) (DORTMUND)

Electrosteel Castings Ltd., Khardah, West Bengal, India. (*Castings*) (CALCUTTA)

Ellerbrock, Hans, Stahlgiesserei und Maschinenfabrik, Hamburg, Germany. (*Castings*) (HAMBURG)

Empire Steel Castings Inc., Reading, Pa., U.S.A. (*Castings*) (PHILADELPHIA)

Empresa Nacional Bazan, El Ferrol del Caudillo, Spain. (*Castings*) (EL FERROL)

Empresa Nacional Siderurgica, S.A., (ENSIDESA), Avilés, Spain. (*Ingots, slabs and billets for re-rolling, plates and sections*) (GIJON)

Endo Iron Works Co. Ltd., Osaka, Japan. (*Forgings*) (KOBE)

Enterprise Engine & Foundry Co., South City, Cal., U.S.A. (*Castings*) (SAN FRANCISCO)

Eschweiler Bergwerks-Verein Hüttenbetriebe, Eschweiler-Aue, Germany. (*Ingots and seamless tubes*) (COLOGNE)

Esco Ltd., Port Coquitlam, B.C., Canada. (*Castings*) (VANCOUVER)

Españoles, Astilleros, S.A.,
Factoria de Reinosa, Spain. (*Ingots, forgings, castings, plates and sections*) (BILBAO)
Factoria de Sestao. (*Small castings, ingots and forgings*) (BILBAO)

Esperance Longdoz S.A., Liege, Belgium. (*Ingots and thin plates*) (ANTWERP)

Etablissement des Constructions et Armes Navales de Guerigny, Guerigny, France. (*Ingots, bars, forgings and castings*) (PARIS)

Euskalduna, Compania, Funicion de Asua, (near Bilbao,) Vizcaya, Spain. (*Castings*) (BILBAO)

Fagersta Bruks Aktiebolag, Fagersta, Sweden (Brukskoncernen).
Works: Fagersta. (*Blooms, billets, forgings, rolled bars and electric resistance welded tubes*) (STOCKHOLM)
Works: Forsbacka. (*Blooms, billets, forged and rolled bars*) (STOCKHOLM)
Works: Osterbybruk. (*Castings, forgings and rolling mill for bars*) (STOCKHOLM)

Faggian, Acciaierie Elettriche Pio, Soc. per Azioni, La Spezia, Italy. (*Small castings*) (LA SPEZIA)

Falck, Acciaierie e Ferriere Lombarde. *Head Office & Works:* Milan, Italy. (*Weldless rolled or drawn tubes*) (MILAN)
"Concordia". *Works:* Sesto San Giovanni. (*Ingots and plates*) (MILAN)
"Unione". *Works:* Sesto San Giovanni. (*Ingots, sections, bars, forgings and castings*) (MILAN)

Falk Corporation, Milwaukee, Wis., U.S.A. (*Castings*) (CHICAGO)

Ferretera Montanesa S.A., Torrelavega, Spain. (*Castings*) (BILBAO)

Ferry-Capitain S.A.R.L., Usines de Bussy-Joinville, France. (*Electric steel castings*) (PARIS)

Feurs, Fonderies & Acieries Electriques de, Feurs, Loire, France. (*Small castings*) (MARSEILLES)

FIAT, Società per Azioni, Sezione Ferriere Piemontesi, Turin, Italy. (*Ingots, plates, sections, also seamless and welded tubes*) (GENOA)

Finkl, A., & Sons Company, Chicago, Ill., U.S.A. (*Forgings*) (CHICAGO)

Fischer, George, Ltd., Schaffhausen, Switzerland. (*Castings*) (WINTERTHUR)

Fit Ferrotubi-Fabbrica Italiana Tubi Ferrotubi, Italy. (*Ingots, billets and weldless rolled and drawn tubes*) (GENOA)

Fives-Lille-Cail, Société de.

Usine de Fives, Lille (Nord), France. (*Forgings*) (VALENCIENNES)

Usine de Denain, Denain (Nord), France. (*Castings, ingots, forgings, blooms, bars and sheets*) (VALENCIENNES)

Flag S.p.A. Marcon (Mestre). (*Small castings*) (VENICE)

Fomas-Forgiatura Moderna Acciai Speciali S.p.A., Osnago, (Como), Italy. (*Forgings*) (MILAN)

Fonderia Acciaieria Giovanni Mandelli, Turin, Italy. (*Castings*) (GENOA)

Fonderie de Fer et d'Acier, Biel, Switzerland. (*Castings*) (WINTERTHUR)

Fonderies Grandry, S.A., Mohon (Ardennes), France. (*Castings*) (VALENCIENNES)

Forjas Alavesas S.A., Vitoria, Spain. (*Ingots, rolled bars and forgings*) (BILBAO)

Frichs A/S, Aarhus, Denmark. (*Castings*) (AALBORG)

Fried. Krupp Huttenwerke A.G., Bochum, Germany.

Works: Bochum. (*Ingots, plates, forgings, castings and bars*) (DUSSELDORF)

Works: Rheinhausen. (*Ingots, bars and sections*) (DUSSELDORF)

Friedrich-Carl-Hütte G.m.b.H., Delligsen über Alfeld/Leine, Germany. (*Castings*) (HANNOVER)

Fucine Meridionali, S.p.A., Bari, Italy. (*Castings and forgings*) (NAPLES)

Fukushima Seiko Co., Ltd., Fukushima, Japan. (*Castings*) (YOKOHAMA)

Funabashi Steel Works Ltd., Funabashi City, Chiba Prefecture, Japan. (*Ingots and flat bars*) (YOKOHAMA)

Funderia, S.A. de, Manresa, Spain. (*Castings*) (BARCELONA)

Fundiciones del Estanda, S.A., Beasain, Spain. (*Castings*) (BILBAO)

Fundiciones Echevarria S.A., Beasain, Guipuzcoa, Spain. (*Ingots, small rolled bars and castings*) (BILBAO)

Fundiciones Especiales Zaragoza, S.A., Zaragoza, Spain. (*Castings*) (BILBAO)

Fundicoes do Rossio de Abrantes, S.A.R.L., Rossio de Abrantes, Portugal. (*Castings*) (LISBON)

Fundidora de Fierro y Acero de Monterrey, S.A., Monterrey, N.L., Mexico. (*Plates*) (TAMPICO)

Ganz-Mavag Mozdony Vagon es Gepgyar, Budapest, Hungary. (*Castings and forgings*) (VIENNA)

General Metals Corporation, Oakland, Cal., U.S.A. (*Castings*) (SAN FRANCISCO)

Generale d'Hydraulique et de Mecanique Usine Metallurgique de Marquise, Rinxent, Pas de Calais, France. (*Castings*) (DUNKIRK)

Gennevilliers, Aciéries de, Gennevilliers, Seine, France. (*Castings*) (PARIS)

Go Iron Works, Ltd., Tarui Works, Tarui, Japan. (*Small castings*) (KOBE)

Gottwald, Leo, Werk Hattingen, Ruhr, Germany. (*Small forgings*) (DORTMUND)

Granite City Steel Co., Granite City, Ill., U.S.A. (CHICAGO)

Great Lakes Steel Corporation, Division of National Steel Corporation, Ecorse, Detroit 29, Michigan, U.S.A. (*Ingots, billets, bars, slabs, plate, blooms, sheet and coiled strip*) (CLEVELAND)

Gresele, Acciaierie Valbruna di Ernesto, Vicenza, Italy. (*Castings, bars, sections and forgings*) (VENICE)

Grossmann, C., Eisen-und Stahlwerk A.G., Solingen-Wald, Germany. (*Castings*) (DUSSELDORF)

Gueugnon, Forges de, Gueugnon, (S & L), France. (*Rolling mill for plates*) (PARIS)

Gussstahlwerk Carl Bönnhoff, Wetter/Ruhr, Germany. (*Ingots and castings*) (DORTMUND)

Gussstahlwerk Risch K.G., Bergisch-Gladbach, Germany. (*Electric steel castings*) (COLOGNE)

Gussstahlwerk Wittman A.G., Hagen-Haspe, Germany. (*Castings*) (DORTMUND)

Gutehoffnungshütte Sterkrade A.G., Werk Sterkrade, Oberhausen-Sterkrade, Germany. (*Forgings*) (DUSSELDORF)

Hadfields Steel Works, Ltd., Alexandria, Sydney, N.S.W. (*Castings and forgings*) (SYDNEY)

Hadfields (W.A.) 1934 Ltd., Perth, Western Australia. (*Castings*) (FREMANTLE)

HADIR, Société des Haut-Fourneaux et Aciéries de Differdange-St.Ingbert-Rumelange, Differdange Works, Luxembourg. (*Sections and bars*) (SAARBRÜCKEN)

Hainaut-Sambre, Société Métallurgiques, S.A., Couillet, Belgium.

Division de Couillet. (*Ingots, blooms, bars, forgings and castings*) (ANTWERP)

Division de Montignies et Chatelineau. (*Rolling mill*) (ANTWERP)

Haine St. Pierre et Lesquin, Aciéries de, Société Anonyme, Haine St. Pierre, Belgium. (*Castings*) (ANTWERP)

Lesquin-lez-Lille (Nord), France. (*Castings*) (VALENCIENNES)

Hakodate Dock Co., Ltd., Hakodate Shipyard, Hakodate, Japan. (*Small forgings and castings*) (YOKOHAMA)

Hallstahammar Aktiebolag, Hallstahammar, Sweden. (*Bars*) (STOCKHOLM)

Haneda Pipe Works Co., Ltd., Tokyo, Japan. (*Seamless tubes*) (YOKOHAMA)

Hatakeyama Iron Works Co., Ltd., Komatsugawa Works, Tokyo, Japan. (*Small forgings*) (YOKOHAMA)

Hawker Siddeley Canada Ltd., Trenton Works, Trenton, N.S. (*Forgings*) (HALIFAX, N.S.)

Heavy Engineering Corp., Ltd., Foundry Forge Plant, P. O. Dhurwa, Ranchi, India. (*Castings*) (JAMSHEDPUR)

Helsingors Skibsvaerft-og Maskinbyggeri A/S, Aktieselskabet, Elsinore, Denmark. (*Forgings and castings*) (COPENHAGEN)

Henricot, Usines Emile, Court St. Etienne, Belgium. (*Castings*) (ANTWERP)

Herchamet S.A.I.C., Fundicion Electrica de Aceros Velez Sarfield, Rosario, Argentina. (*Castings*) (BUENOS AIRES)

Hierros y Aceros Industriales S.A., San Adrian de Besos, Barcelona, Spain. (*Small castings*) (BARCELONA)

Hindustan Steel Ltd.

- Rourkela, Orissa, India. (*Ingots, slabs and plates*) (CALCUTTA)
- Durgapur Steel Plant, West Bengal, India. (*Blooms, billets, bars and sections*) (CALCUTTA)
- Bhilai Steel Project, Bhilai, Madhya Pradesh, India. (*Ingots, blooms, billets and sections*) (CALCUTTA)

d'Hirson S.A., Aciéries, Hirson, Aisne, France. (*Castings*) (VALENCIENNES)

Hitachi, Ltd.

- Hitachi Works, (Yamate Factory), Hitachi-shi, Japan. (*Castings*) (YOKOHAMA)
- Kasado Works, Kudamatsu, Japan. (*Castings and forgings*) (SHIMONOSEKI)
- Katsuta Works, Katsutashi, Ibaragi-ken, Japan. (*Ingots, forgings and castings*) (YOKOHAMA)

Hitachi Metals, Ltd.

- Yasugi Works, Yasugi, Japan. (*Ingots, bars and forgings*) (KOBE)
- Tobata Works, Tobata, Japan. (*Castings*) (SHIMONOSEKI)

Hitachi Shipbuilding & Engineering Co., Ltd.

- Chikko Shipyard, Osaka, Japan. (*Ingots, castings and forgings*) (KOBE)
- Innoshima Shipyard, Innoshima, Japan. (*Forgings and small castings*) (KOBE)

Hoesch Hüttenwerke, A.G., Dortmund, Germany.

- Werk Phoenix Hörde, Dortmund-Hörde. (*Ingots, plates and castings*) (DORTMUND)
- Werk Union, Dortmund. (*Bars and sections*) (DORTMUND)
- Werk Westfalenhütte, Dortmund. (*Ingots, billets, plates, bars and sections*) (DORTMUND)

Hoganas A/B, Hoganas, Sweden. (*Castings*) (HELSINGBORG)

Hokuriku Kogyo Co., Ltd., Sanjo Plant, Sanjo, Niigata Prefecture, Japan. (*Small forgings*) (YOKOHAMA)

Howa Machinery, Ltd., Inazawa Plant, Aichi Prefecture, Japan. (*Castings*) (KOBE)

Hubner-Vamag, Vereinigte Armaturenfabriken, Aktiengesellschaft, Vienna, Austria. (*Castings*) (VIENNA)

Hults Bruk A.B., Aby, Sweden. (*Castings*) (STOCKHOLM)

Huta 1 Maja, Gliwice, Poland. (*Ingots and forgings*) (KATOWICE)

Huta Baildon, Katowice, Poland. (*Ingots, forgings and bars*) (KATOWICE)

Huta Batory, Chorzow-Batory, Poland. (*Forgings, plates and tubes*) (KATOWICE)

Huta Bierut, Czestochowa, Poland. (*Seamless tubes*) (KATOWICE)

Huta Bobrek, Bytom, Poland. (*Ingots, slabs and blooms*) (KATOWICE)

Huta im. M. Buczka, Sosnowiec, Poland. (*Seamless tubes*) (KATOWICE)

Huta Dzierzynski, Dabrowa Gornicza, Poland. (*Billets, sections and bars*) (KATOWICE)

Huta Florian, Swietochlowice, Poland. (*Angles and bars*) (KATOWICE)

Huta Jednosc, Siemianowice Slaskie, Poland. (*Ingots and seamless tubes*) (KATOWICE)

Huta Kosciuszko, Chorzow, Poland. (*Billets, blooms, sections and rivet bars*) (KATOWICE)

Huta Labedy, Labedy, Poland. (*Flats and sections*) (KATOWICE)

Huta im. Lenina, Krakow, Poland. (*Ingots, slabs, plates up to 12 mm*) (KATOWICE)

Huta Malapanew, Ozimek k/Opola, Poland. (*Castings*) (KATOWICE)

Huta Nowotko, Ostrowiec Swietokrzyski, Poland. (*Sections*) (KATOWICE)

Huta Pokoj, Ruda Slaska, Poland. (*Plates, sections and small forgings*) (KATOWICE)

Huta Stalowa Wola, Stalowa Wola, Poland. (*Castings, forgings, plates and sections*) (KATOWICE)

Huta Zawiercie, Zawiercie, Poland. (*Flats and bars*) (KATOWICE)

Hüttenwerk Oberhausen A.G., Oberhausen, Germany. (*Ingots, plates, sections and bars*) (DUSSELDORF)

Hüttenwerke Siegerland A.G., Niederschelden, Germany. (*Ingots and slabs*) (COLOGNE)

Ilseder Hütte/Peine, Hüttenbetriebe, Peine, Germany. (*Ingots, billets, sections and bars*) (HANOVER)

d'Imphy, Societe Metallurgique, Acieries d'Imphy (Nièvre), France. (*Ingots, forgings, bars and sections*) (PARIS)

Indian Iron & Steel Co., Ltd.

- Burnpur Works, Burnpur, West Bengal, India. (*Sections and angles*) (CALCUTTA)
- Kulti Iron Works, Kulti, India. (*Castings*) (CALCUTTA)

Indian Tube Company Ltd., Jamshedpur, India. (*Seamless tubes*) (CALCUTTA)

Industrial Steels, Ltd., Lidcombe, Sydney, N.S.W., Australia. (*Castings*) (SYDNEY)

Industrias del Besos, S.A., Barcelona, Spain. (*Small sections and bars*) (BARCELONA)

Industrias Mecanicas, Sociedad Anonima, Barcelona, Spain. (*Castings*) (BARCELONA)

Industrija Masina i Livnica, Tuzla, Yugoslavia. (*Castings*) (SPLIT)

Inland Steel Co., Indiana Harbor, Ind., U.S.A. (*Ingots, blooms, billets and slabs*) (CHICAGO)

Interprovincial Steel and Pipe Corporation Ltd., Regina, Saskatchewan, Canada. (*Plates*) (TORONTO)

Ishikawajima-Harima Heavy Industries Co., Ltd., Aioi Works, Aioi, Japan. (*Castings and forgings*) (KOBE)

Ishikawajima-Harima Heavy Industries Co., Ltd., Tokyo, Japan. (*Ingots, forgings and castings*) (YOKOHAMA)

"ITALSIDER" S.p.A., Head Office: Via Corsica 4, Genoa, Italy.

S.I.A.C., Genoa. (*Ingots, forgings, plates and castings*) (GENOA)

Stabilimento di Lovere. (*Sections, bars, castings and forgings*) (MILAN)

Stabilimento di Marghera. (*Rolling mills for small sections and bars*) (VENICE)

Stabilimento di Portovecchio di Piombino. (*Ingots, blooms, sections and bars*) (LEGHORN)

Stabilimento di Taranto. (*Ingots, slabs and plates*) (NAPLES)

Oscar Sinigaglia Works, Genoa-Cornigliano. (*Ingots, slabs and plates*) (GENOA)

"ITALSIDER" S.p.A. Centro Siderurgico di Bagnoli, Naples. (*Ingots, sections and bars*) (NAPLES)

Izuo Chukosho Co., Ltd., Osaka, Japan. (*Castings*) (KOBE)

Jadot, Société Anonyme Etablissements, Beloeil, Belgium. (*Small castings*) (ANTWERP)

Japan Drop Forge Co., Ltd., Amagasaki, Japan. (*Small forgings*) (KOBE)

Japan Iron-Sand Steel Co. Ltd., Shikama Works, Himeji, Japan. (*Ingots bars and sections*) (KOBE)

Japan Special Steel Co., Ltd., Tokyo, Japan. (*Ingots, forgings, blooms, billets and bars*) (YOKOHAMA)

Japan Steel Works Ltd.

Hiroshima Works, Hiroshima, Japan. (*Forgings and castings*) (SHIMONOSEKI)

Muroran Works, Muroran, Japan. (*Ingots, forgings, castings and plates*) (YOKOHAMA)

Jemappes, Société Anonyme Forges et Laminoirs de, Jemappes, near Mons, Belgium. (*Ingots, blooms and bars*) (ANTWERP)

Joban Machinery Co. Ltd., Uchigo Factory, Fukushima Prefecture, Japan. (*Castings*) (YOKOHAMA)

Jonan Iron Works Co., Ltd., Haneda Works, Tokyo, Japan. (*Small forgings*) (YOKOHAMA)

Jones & Laughlin Steel Corporation, Pittsburgh, Pa., U.S.A. (CLEVELAND, O.)

Jorgensen, Earle, M. Co., Forge Division, Seattle, Washington. (SEATTLE)

K.G.M.-Altalanos Gepipari Igazgatosag, Budapest, Hungary.

Works: Öntödei Vallalat 1. sz., Gyára, Budapest. (*Castings*) (VIENNA)

K.G.M. Jármuipari Igazatóság, Budapest, Hungary.

Works: Magyar Vagon-és Gépgyár, Györ. (*Castings*) (VIENNA)

K.G.M. Vaskohászati Igazgatóság, Budapest, Hungary.

Works: Lenin Kohászati Müvek, Miskole-Diósgyör. (*Ingots, slabs, sections, bars, castings and forgings*) (VIENNA)

Works: Dunai Vasmü, Dunaujváros. (*Ingots, slabs and plates*) (VIENNA)

Works: Dunai Vasmü, Lörinci Hengermüve, Budapest. (*Rolling mill for plates*) (VIENNA)

Works: Ozdi Kohászati üzemek, Ozd. (*Ingots, slabs, plates, sections and bars*) (VIENNA)

K.K. Teikoku Kokan Seizosho, Osaka, Japan. (*Seamless tubes*) (KOBE)

Kaiser Steel Corporation, Fontana, Cal., U.S.A. (*Ingots and plates*) (LOS ANGELES)

Kakegawa Endo Iron Works Co., Ltd., Kakegawa, Japan. (*Forgings*) (YOKOHAMA)

Kansai Steel Corp., Sakai, Japan. (*Ingots, bars and flat bars*) (KOBE)

Kansai Tekko Co., Ltd., Amagasaki, Japan. (*Small forgings*) (KOBE)

Kanthal, A/B, Hallstahammar, Sweden. (*Ingots, billets, bars and castings*) (STOCKHOLM)

Kanto Special Steel Works, Ltd., Fujisawa, Kanagawa Pref., Japan. (*Forgings*) (YOKOHAMA)

Kawaguchi Kinzoku Kogyo Kabushiki Kaisha, Kawaguchi, Japan. (*Castings*) (YOKOHAMA)

Kawasaki Heavy Industries Ltd.

Crushing Plant Mfg. Division, Japan. (*Castings*) (YOKOHAMA)

Hyogo Cast Steel Works, Kobe. (*Castings*) (KOBE)

Kobe Works, Kobe. (*Castings*) (KOBE)

Kawasaki Steel Corporation.

Chiba Works, Chiba. (*Slabs and plates*) (YOKOHAMA)

Chita Works, Handa City. (*Ingots and castings*) (KOBE)

Fukiai Works, Kobe. (*Blooms and sections*) (KOBE)

Hyogo Works, Kobe. (*Castings and forgings*) (KOBE)

Mizushima Works, Mizushima, Japan. (*Ingots, forgings, castings, bars and plates*) (KOBE)

Nishinomiya Works, Nishinomiya. (*Ingots and thin plates*) (KOBE)

Kilby Steel Co., Furnace Division, Anniston, Alabama, U.S.A. (*Ingots*) (MOBILE)

Kinka Kikai Co., Ltd., Gifu, Japan. (*Castings*) (KOBE)

Klafreströms Bruk, A/B., Klavreström, Sweden. (*Small castings*) (GOTHENBURG)

Klinger, Rich., Aktiengesellschaft, Gumpoldskirchen, near Vienna, Austria. (*Small castings*) (VIENNA)

Klöckner-Werke A.G.

Works: Georgsmarienwerke, Osnabrück, Germany. (*Ingots, bars, forgings and castings*) (HANNOVER)

Works: Hütte Bremen, Germany. (*Plates*) (BREMEN)

Works: Hütte-Haspe, Hagen-Haspe, Germany. (*Rolling mills for bars*) (DORTMUND)

Works: Mannstaedt-Werke, Troisdorf, Germany. (*Rolling mills for sections*) (COLOGNE)

Knorr-Bremse G.m.b.H., Volmarstein-Schmandbruch, Germany. (*Castings*) (DORTMUND)

Kobe Steel Ltd.

Works: Amagasaki, Japan. (*Ingots, sections and bars*) (KOBE)

Works: Kakogawa Plant, Kakogawa City, Hyogo Prefecture, Japan. (*Rolling mills for plates*) (KOBE)

Works: Kobe, Japan. (*Ingots, blooms, billets, bars castings and seamless tubes*) (KOBE)

Works: Takasago Plant, Takasago, Japan. (*Ingots, forgings and castings*) (KOBE)

Kockums Jernverk, Kallinge, Sweden. (*Ingots and castings*) (MALMO)

Kohlswa Jernverks Aktiebolag. (*Ingots, forgings and castings*) (STOCKHOLM)

Kokko Steel Works, Ltd., Osaka, Japan. (*Ingots, bars and castings*) (KOBE)

Kokoku Steel Casting Co., Ltd., Osaka, Japan. (*Castings*) (KOBE)

Komatsu Ltd.

Awazu Plant, Komatsu, Japan. (*Castings*) (KOBE)

Osaka Plant, Hirakata, Osaka Prefecture, Japan. (*Castings*) (KOBE)

Koninklijke Demka Staalfabrieken N.V., Utrecht, Holland. (*Rolling mill for bars*) (AMSTERDAM)

Koninklijke Nederlandsche Hoogovens & Staalfabrieken N.V. (Royal Netherlands Blast-furnaces & Steel Works, Ltd.), Ymuiden, Holland. (*Plates and sections*) (AMSTERDAM)

Kotobuki Kogyo Co., Ltd., Hiro Works, Kure, Japan. (*Castings*) (HIROSHIMA)

Krauss-Maffei A.G., München-Allach, Germany. (*Castings*) (AUGSBURG)

Kruiner Gussstahlwerk, Gevelsberg, Germany. (*Castings*) (DORTMUND)

Kubota Ltd., Hirakata Plant, Hirakata, Osaka, Japan. (*Castings*) (KOBE)

Kumardhubi Engineering Works Ltd., P.O. Box Kumardhubi, Dist. Dhanbad, (Bihar), India. (*Castings*) (CALCUTTA)

Kureha Seiko Co. Ltd., No. 1 5-Chome Takeshima-Cho, Nishiyodogawa-Ku, Osaka, Japan. (*Castings*) (KOBE)

Kureha Seitetsu Co., Ltd., Toyama, Japan. (*Ingots*) (YOKOHAMA)

Kurimoto Iron Works Ltd., Kagaya Factory, Osaka, Japan. (*Castings*) (KOBE)

Latrobe Forge & Spring, Inc. Latrobe, Pa., U.S.A. (*Ingots and forgings*) (CLEVELAND, O.)

Lebanon Steel Foundry, Lebanon, Pa., U.S.A. (*Small castings*) (PHILADELPHIA)

Leonard-Giot, Société Anonyme Usines & Aciéries, Marchienne-au-Pont, Belgium. (*Castings*) (ANTWERP)

Letson & Burpee, Ltd., Richmond, British Columbia, Canada. (*Small castings*) (VANCOUVER)

Llodio, Ltda., Aceros de, Llodio, near Bilbao, Spain. (*Castings, ingots, forgings and rolled bars*) (BILBAO)

Lokomo Oy, Tampere, Finland. (*Ingots, forgings and castings*) (ÅBO)

Los Angeles Steel Casting Co., Los Angeles, Cal., U.S.A. (*Castings*) (LOS ANGELES)

Luigi Giudici, Societa per Asioni, Rescaldina, Milan, Italy. (*Small castings*) (MILAN)

Lukens Steel Company, Coatesville, Pa., U.S.A. (*Plates*) (PHILADELPHIA)

Luzuriaga, Victorio, S.A., Pasajes, Guipuzcoa, Spain. *Works:* Lasarte, Nr. San Sebastian, Guipuzcoa. (*Castings*) (BILBAO)

Lynn Macleod Metallurgy Ltd., Thetford Mines, P.Q., Canada. (*Castings*) (MONTREAL)

Maekawa Electric Steel Castings Co.

Osaka, Japan. (*Castings*) (KOBE)

Tobata Factory, Kitakyushu, Japan. (*Castings*) (SHIMONOSEKI)

Maizuru Jukogyo Ltd., Maizuru, Japan. (*Small castings*) (KOBE)

Makine ve Kimya Endustri, Celik Fabrikasi, Kirikkale, Turkey. (*Ingots, forgings, rolled sections and bars*) (ISTANBUL)

Mangolds Engineering, Port Elizabeth, South Africa. (*Small castings*) (DURBAN)

Manitoba Rolling Mills Division of Dominion Bridge Co., Ltd., Selkirk, Manitoba, Canada. (*Billets, bars and sections*) (MONTREAL)

Mannesmann A.G. Huttenwerke, Duisburg-Huckingen. (*Ingots, slabs and bars*) (DUSSELDORF)

Mannesmannrohren-Werke G.m.b.H., Dusseldorf. (*Seamless and welded tubes*) (DUSSELDORF)

Marathon Argentina, Aceros Finos y Especiales S.A., Villa Constitucion, Santa Fe, Argentina. (*Ingots, forgings and forged bars*) (BUENOS AIRES)

Maritime Steel and Foundries, Ltd., New Glasgow, Nova Scotia. (*Small castings*) (HALIFAX, N.S.)

Marrel Frères, Société Anonyme des Etablissements, Usine des Etaings, near Rive-de-Gier (Loire), France. (*Ingots, forgings, plates and bars*) (MARSEILLES)

Mason & Cox, Pty. Ltd., Adelaide, S. Australia. (*Castings*) (ADELAIDE)

Material y Construcciones S.A., Barcelona, Spain. (*Castings*) (BARCELONA)

Matsuya Kogyo Co., Ltd., Fukuoka, Japan. (*Small forgings*) (SHIMONOSEKI)

Maubeuge, Société Anonyme de la Fabrique de Fer de, Louvroil (Nord), France. (*Ingots*) (VALENCIENNES)

Maximilianshütte, Eisenwerk-Gesellschaft m.b.H., Sulzbach-Rosenberg, Bavaria, Germany. Haidhof Works: (*Ingots, billets, bars, small sections and thin plates*) (AUGSBURG)

Meridionali, Acciaierie e Tubificio, S.p.A., Bari, Italy. (*Castings and weldless rolled or drawn tubes*) (NAPLES)

Metal & Steel Factory, Ishapore, West Bengal, India. (*Ingots, blooms, billets, forgings, castings and bars*) (CALCUTTA)

Metallurgica Marcora S.n.C., Busto Arsizio (Varese), Italy. (*Weldless rolled and drawn tubes*) (MILAN)

Metalurgica Duarte Ferreira S.A.R.L., Tramagal, Portugal. (*Castings*) (LISBON)

Meuse, Les Acieries de la, S.A., Cheratte-lez-Liege, Belgium. (*Castings*) (ANTWERP)

Meuse, Les Usines à Tubes de la, Flémalle-Haute, Belgium. (*Seamless tubes*) (ANTWERP)

Meuse, Société Métallurgique de la, Forges et Aciéries de Stenay, Stenay, Meuse. (*Castings*) (VALENCIENNES)

Meyer, F., Stahl-, Draht- und Rohrenwerke, Dinslaken, Germany. (*Ingots, billets for tubes and bars*) (DUSSELDORF)

Midvale-Heppenstall Company, Nicetown, Philadelphia, Pa., U.S.A. (*Forgings*) (PHILADELPHIA)

Miniere et Metallurgique de Rodange S.A., Rodange, Luxembourg. (*Sections*) (SAARBRUCKEN)

Mitsubishi Heavy Industries Ltd., Yokohama Shipyard and Engine Works, 1-1 Midoricho, Nishi-Ku, Yokohama, Japan. (*Castings*) (YOKOHAMA)

Hiroshima Works, Hiroshima, Japan. (*Ingots, castings and small forgings*) (SHIMONOSEKI)

Kobe Shipyard & Engine Works, Kobe, Japan. (*Ingots, small forgings and castings*) (KOBE)

Mihara Machinery Works, Mihara, Japan. (*Castings and forgings*) (KOBE)

Nagasaki Works, Nagasaki, Japan. (*Castings*) (NAGASAKI)

Shimonoseki Shipyard & Engine Works, Shimonoseki, Japan. (*Small forgings*) (SHIMONOSEKI)

Takasago Machinery Works, Takasago, Japan. (*Forgings*) (KOBE)

Mitsubishi Metal Mining Co., Ltd., Okegawa Plant, Saitama Prefecture, Japan. (*Small castings*) (YOKOHAMA)

Mitsubishi Steel Manufacturing Co., Ltd., Tokyo, Japan.

Hirota Works, Fukushima Pref. (*Castings*) (YOKOHAMA)

Nagasaki Works, Nagasaki, Japan. (*Ingots, blooms, plates, forgings and castings*) (NAGASAKI)

Tokyo Steel Works. (*Billets, bars and small forgings*) (YOKOHAMA)

Mitsui Miike Machinery Co., Ltd., Miike Works, Omuta-shi, Japan. (*Castings*) (SHIMONOSEKI)

Mitsui Shipbuilding & Engineering Co., Ltd., Japan.

Fujinagata Works, Osaka, Japan. (*Forgings*) (KOBE)

Tamano Works, Tamano, Japan. (*Ingots, forgings and castings*) (KOBE)

Mitsumoto Valve Manufacturing Co., Ltd., Domyoji, Osaka, Japan. (*Small forgings and small castings*) (KOBE)

Miyazaki Iron Works Co., Ltd., Osaka, Japan. (*Small forgings*) (KOBE)

Motala Verkstad, A/B, Motala Verkstad, Sweden. (*Ingots and castings*) (GOTHENBURG)

Mukand Iron & Steel Works, Ltd., Kurla, Bombay, 70, India. (*Castings*) (BOMBAY)

Nakayama Steel Products Co. Ltd., Tsurumi Works, Tsurumi, Yokohama, Japan. (*Ingots and plates*) (YOKOHAMA)

Nakayama Steel Works Ltd., Osaka, Japan. (*Ingots and plates*) (KOBE)

National Forge Co.

Erie Division, Erie, Pennsylvania, U.S.A. (*Ingots, forgings and castings*) (CLEVELAND, O.)

Irvine, Warren County, Pennsylvania, U.S.A. (*Ingots and forgings*) (CLEVELAND, O.)

National Iron & Steel Co., Ltd., Stephen House, Calcutta, 1, India. (*Castings*) (CALCUTTA)

National Iron & Steel Mills Ltd., Jalan Besi Baja, Jurong Industrial Estate, Singapore. (*Small sections and bars*) (SINGAPORE)

Nazionale "Cogne", S.p.A. *Head Office:* Turin. *Works:* Aosta. (*Ingots, forgings, plates, sections and bars*) (GENOA)

Neunkircher Eisenwerk A.G., Neunkirchen/Saar, Germany.

Neunkirchen Works. (*Ingots, bars and sections*) (SAARBRUCKEN)

Homburg Works. (*Ingots and seamless tubes*) (SAARBRUCKEN)

Newport News Shipbuilding & Dry Dock Co., Newport News, Va., U.S.A. (*Castings and forgings*) (NEWPORT NEWS)

Nicolacopoulos, G., & Co., Athens, Greece, Steelworks at Eleusis. (*Castings*) (PIRÆUS)

Niederrheinische Hutte, A.G., Duisburg, Germany. (*Rolling mill for narrow flats and sections*) (DUSSELDORF)

Nippon Chuzo Kabushiki Kaisha, Kawasaki, Japan. (*Castings*) (YOKOHAMA)

Nippon Kokan Kabushiki Kaisha.
- Asano Dockyard, Yokohama, Japan. (*Small forgings*) (YOKOHAMA)
- Fukuyama Iron Works, Fukuyama, Japan. (*Ingots, blooms and plates*) (KOBE)
- Keihin Iron Works. (YOKOHAMA)
  - Mizue Plant. (*Plates up to 12,5 mm in thickness*)
  - Tsurumi Plant. (*Ingots and plates*)
  - Tubular & Structural Products Dept. (*Tubes, bars and sections*)

Nippon Sharyo Seizo Kaisha, Ltd., Nagoya, Japan. (*Castings*) (KOBE)

Nippon Stainless Steel Co., Ltd., Naoetsu Works, Niigata, Japan. (*Ingots, forgings, castings and plates*) (YOKOHAMA)

Nippon Steel Corporation.
- Engineering, Machinery and Foundry Division, Tobata, Kitakyushu, Japan. (*Castings and forgings*) (SHIMONOSEKI)
  - Hirohata Works, Himeji City, Japan. (*Ingots, billets, plates and sections*) (KOBE)
  - Kamaishi Works, Kamaishi, Japan. (*Sections and bars*) (YOKOHAMA)
  - Kimitsu Works, Kimitsu, Japan. (*Ingots and plates*) (YOKOHAMA)
  - Muroran Works, Hokkaido, Japan. (*Billets, sections and bars*) (YOKOHAMA)
  - Nagoya Works, Nagoya, Japan. (*Ingots and plates*) (KOBE)
  - Sakai Works, Sakai, Osaka, Japan. (*Ingots, sections and thin plates*) (KOBE)
  - Tobata Area Works, Japan. (*Ingots and plates*) (SHIMONOSEKI)
  - Tokyo Works, Japan. (*Rolling mills for weldless, rolled or drawn tubes*) (YOKOHAMA)
  - Yawata Area Works, Japan. (*Plates, sections, ingots and forgings*) (SHIMONOSEKI)

Nippon Steel Foundry Co., Ltd., Osaka, Japan. (*Castings*) (KOBE)

Nippon Yakin Kogyo Co., Ltd., Kawasaki, Japan. (*Ingots, forgings, bars and thin plates*) (YOKOHAMA)

Nisshin Seiko Co., Ltd., Shikama Plant, Himeji, Japan. (*Rolled sections and bars*) (KOBE)

Nisshin Steel Works, Ltd., Kure Works, Kure, Japan. (*Ingots, blooms, billets and strip*) (SHIMONOSEKI)

Nittoku Metal Industry Co., Ltd., Tokyo, Japan. (*Small forgings*) (YOKOHAMA)

Nordische Stahlwerke, Bach & Co., Neumünster, Germany. (*Castings*) (KIEL)

Nordiska Armaturfabrikerna, A/B, Linköping, Sweden. (*Castings*) (STOCKHOLM)

Norrbottens Järnverk Aktiebolag, Lulea, Sweden. (*Ingots, slabs, blooms and billets, bars and sections*) (STOCKHOLM)

Norsk Jernverk, A/S., Mo-i-Rana, Norway. (*Electric steel ingots, billets, sections and bars*) (OSLO)

Nová hut̆ Klementa Gottwalda, národni podnik (New Metallurgical Works of Klement Gottwald, National Corporation), Ostrava-Kunčice, Czechoslovakia. (*Ingots and forgings*) (VIENNA)

Nueva Montana Quijano S.A., Nueva Montana, Santander, Spain. (*Castings*) (BILBAO)

Oesterreichisch-Alpine Montangesellschaft, Vienna.
- *Works:* Donawitz, Styria. (*Sections and strip*) (VIENNA)
- *Works:* Kindberg, Styria. (*Rolling mills for small sections, bars and strip*) (VIENNA)
- *Works:* Traisen, Low Austria. (*Castings*) (VIENNA)

Ohio Steel Foundry Co., Lima, Ohio, U.S.A. (*Ingots, forgings and castings*)

Ohtani Heavy Industrial Co., Ltd., Amagasaki Plant, Amagasaki, Japan. (*Plates up to 12,5 mm. in thickness*) (KOBE)

Okamoto Iron Works Co., Kobe, Japan. (*Forgings*) (KOBE)

Okano Valve Manufacturing Co., Ltd., Moji. *Works:* Yukuhashi, Japan. (*Small castings and small forgings*) (SHIMONOSEKI)

Olarra S.A.
- *Works:* Erandio, Bilbao Spain. (*Ingots and small bars*) (BILBAO)
- *Works:* Larrondo, Lujua, Vizcaya, Spain. (*Ingots and rolled bars*) (BILBAO)

Olympic Steel Works, Seattle, Wash., U.S.A. (*Castings*) (SEATTLE)

Onomichi Anchor Manufacturing Co., Ltd., Onomichi, Japan. (*Castings*) (KOBE)

Orion S.p.A., Porto Industriale, Trieste, Italy. (*Forgings and castings*) (TRIESTE)

Osaka Chain & Machinery Manufacturing Co., Ltd., Kaizuka Works, Osaka, Japan. (*Small castings*) (KOBE)

Osaka Shipbuilding Co., Ltd., Taira Steel Works, Taira City, Fukushima Prefecture, Japan. (*Castings*) (YOKOHAMA)

Osaka Steel Casting Co., Ltd., Osaka, Japan. (*Small castings*) (KOBE)

Osaka Steel Tube Co., Ltd., Sasebo Works, Sasebo, Japan. (*Seamless tubes*) (NAGASAKI)

Oxelosunds Jarnverk, Oxelosund, Sweden. (*Ingots, rolled slabs and plates*) (STOCKHOLM)

Ozuki Seikosho, Ltd., Shimonoseki, Japan. (*Castings*) (SHIMONOSEKI)

Pacific Metals Company Limited.
- Naoetsu Factory, Naoetsu, Niigata, Japan. (*Ingots and castings*) (YOKOHAMA)
- Toyama Factory, Toyama City, Japan. (*Ingots and forgings*) (YOKOHAMA)

Pacific States Steel Corporation, Union City, Cal., U.S.A. (*Ingots, sections and bars*) (SAN FRANCISCO)

Pacific Steel Castings Co., Berkeley, Cal., U.S.A. (*Castings*) (SAN FRANCISCO)

Pacifico, Compañia de Acero del, S.A., Talcahuano, Chile. (*Ingots, plates, bars and sections*) (VALPARAISO)

Paderwerk Gebr. Benteler, Schlossneuhaus, Germany. (*Seamless tubes*) (DORTMUND)

Paris et d'Outreau, Aciéries de, Société Anonyme, Usine d'Outreau, Pas de Calais, France. (*Castings*) (DUNKIRK)

Paris-Seine, Fonderies et Aciéries de, Usine de la Folie, Avenue de Bobigny, Noisy le Sec (Seine), France. (*Castings*) (PARIS)

Penn Steel Castings Co., Chester, Pa., U.S.A. (*Castings*) (PHILADELPHIA)

Pennsylvania Forge, Division of Chemetron Corporation, Tacony, Philadelphia, 35, Pa., U.S.A. (*Forgings*) (PHILADELPHIA)

Pennsylvania Steel Foundry and Machine Company, Hamburg, Pa., U.S.A. (*Castings*) (PHILADELPHIA)

Phoenix Steel Corporation.
- *Works*: Claymont, Delaware, U.S.A. (*Plates*) (PHILADELPHIA)
- *Works:* Structural Division, Phoenixville, Pa., U.S.A. (*Sections, bars and rotary forged seamless tubes*) (PHILADELPHIA)

Pittsburgh Steel Company, Pittsburgh 30, Pa., U.S.A.
- *Works:* Monessen, Pa. (*Ingots, billets and slabs*) (CLEVELAND, O.)
- *Works:* Allenport, Pa. (*Rolling mills*) (CLEVELAND, O.)

Pohlig-Heckel-Bleichert, Vereinigte Maschinenfabriken A.G., Abt. Stahlformgiesserei, Werk Heckel, Rohrbach/Saar, Germany. (*Castings*) (SAARBRÜCKEN-SAAR)

Pompey, Société des Aciéries de.
- Usine de Pompey, Meurthe & Moselle, France. (*Ingots, blooms, billets, plates, angles and round bars*) (SAARBRÜCKEN-SAAR)
- Usine du Manoir à Pitres, Eure, France. (*Castings*) (ROUEN)

Pont A Mousson, Societe des Fonderies de, Usine de Fumel, France. (*Castings, centrifugal cast pipes*) (MARSEILLES)

Porter, H. K. (France) Acieries Division Marpent, Marpent (Nord), France. (*Castings*) (VALENCIENNES)

Provence, Fonderies et Aciéries de, Marseilles, France. (*Castings*) (MARSEILLES)

Quaker Alloy Casting Co., Myerstown, Pa., U.S.A. (*Small castings*) (PHILADELPHIA)

Raahe Oy, Raahe, Finland. (*Small castings*) (ÅBO)

Ramnas Bruks Aktiebolag, Ramnas, Sweden. (*Rolling mills for bars*) (STOCKHOLM)

Rautaruukki Oy, Raahe, Finland. (*Ingots and plates*) (ÅBO)

Republic Steel Corporation, Cleveland, O., U.S.A.
- Alabama City, Ala., U.S.A. (MOBILE, ALA.)
- Buffalo Plant, Buffalo. N.Y., U.S.A. (CLEVELAND,O.)
- Central Alloy District, Massillon Plant, Massillon, O., U.S.A. (CLEVELAND, O.)
- Chicago Plant, Chicago, Ill., U.S.A.
  - *Works:* 118th Street, Chicago. (*Rolling mills*)
  - East Chicago, Ind. (*Angles and bars*) (CHICAGO)
- Cleveland District, Cleveland, O., U.S.A. (CLEVELAND, O.)
  - Corrigan McKinney Plant. (*Ingots, blooms and billets*)
  - Upson Nut Plant. (*Round and square bars*)
- Youngstown District, Youngstown, O., U.S.A. (CLEVELAND, O.)

Rheinstahl Giesserei A.G., Gussstahlwerk Gelsenkirchen. (*Castings*) (DUSSELDORF)

Rheinstahl Giesserei A.G., Gussstahlwerk Oberkassel, Dusseldorf-Oberkassel, Germany. (*Ingots and castings*) (DUSSELDORF)

Rheinstahl Hüttenwerke, A.G.
- Werk Friedrich Wilhelms-Hütte, Mulheim und Meiderich, Germany. (*Castings*) (DUSSELDORF)
- Henrichshütte, Hattingen-Ruhr. (*Ingots, plates, forgings* and *castings*) (DORTMUND)

Riken Tanzo Co., Ltd., Maebashi Plant, Maebashi, Japan. (*Small forgings*) (YOKOHAMA)

Rikimi Cast Steel Co., Ltd., Osaka, Japan. (*Small castings*) (KOBE)

Röchling'sche Eisen-und Stahlwerke G.m.b.H., Völklingen, Saar. (*Castings, ingots, billets, bars and forgings*) (SAARBRÜCKEN-SAAR)

Rohrenwerke Bous G.m.b.H., Bous/Saar, Germany. (*Seamless tubes*) (SAARBRUCKEN)

Rosenlew, Oy W., A/B, Porin Konepaja, Pori, Åbo. (*Small castings*) (ÅBO)

Rotterdamsche Droogdok Maatschappij, Rotterdam, Holland. (*Ingots, forgings and small castings*) (ROTTERDAM)

Rudarsko - Metalurski Kombinat - Zenica, Zeljezara Zenica, Zenica, Yugoslavia. (*Billets, bars, sections and forgings*) (SPLIT)

Rudnici I Zelezara Smederevo, Smederevo, Yugoslavia. (*Small castings*) (SPLIT)

Rudnici I Zelezarnica, "Skopje", Skopje, Yugoslavia. (*Plates*) (SPLIT)

S.A.F.A.S.—Societa Azionaria Fonderia Acciai Speciali, Tavernelle di Altavilla Vicentina (Vicenza), Italy. (*Castings*) (VENICE)

S.A.F.A.U. Ferriere Acciaierie di Udine, Udine, Italy. (*Ingots, forgings, blooms, bars and sections*) (TRIESTE)

S.A.F.E. Société Aciers Fins de l'Est, Hagondange, Moselle, France. (*Ingots, blooms, billets, bars, plates and sheet*) (SAAR)

Safog, S.A., Fonderie Officine di Gorizia, Gorizia, Italy. (*Castings*) (TRIESTE)

Safog, S.A.,—Stabilimento di Napoli, Naples, Italy. (*Castings*) (NAPLES)

Salon Sahko- Ja Konetehdas Oy, Salo, Finland. (*Small castings*) (ÅBO)

Salzgitter Hüttenwerk A.G., Salzgitter-Drütte, Germany. (*Ingots, plates, bars and sections*) (HANNOVER)

Sambre et Meuse, Société Anonyme des Usines et Aciéries de.
Usines de Feignies, Feignies (Nord), France. (*Castings*) (VALENCIENNES)
Usines de Saint Brieuc (Côtes-du-Nord), France. (*Small castings*) (NANTES)

Sande Giesserei, Sande-Oldenburg, Germany. (*Castings*) (EMDEN)

Sandvikens Jernverks Aktiebolag, Sandviken, Sweden. (*Ingots, forgings and tubes*) (STOCKHOLM)

Sanyo Special Steel Co., Ltd., Himeji, Japan. (*Ingots, forgings and rolled bars*) (KOBE)

Sasebo Heavy Industries Co., Ltd., Sasebo, Japan. (*Ingots, forgings and castings*) (NAGASAKI)

Saut-du-Tarn, Société Anonyme des Forges et Aciéries du, Saint-Juery (Tarn), France. (*Castings*) (MARSEILLES)

Scaw Metals, Ltd., Union Junction, Transvaal, S. Africa. (*Rivet bars, small rolled sections and castings*) (VEREENIGING)

Schmidt & Clemens, Edelstahlwerk, Kaiserau b/Engelskirchen, Bez. Köln, Germany. (*Ingots, forgings, castings and bars*) (COLOGNE)

Schoeller-Bleckmann Stahlwerke A.G., Vienna.
Works: Muerzzuschlag-Hoenigsberg, Styria. (*Bars*) (VIENNA)
Works: Ternitz, Low Austria. (*Castings, forgings and bars*) (VIENNA)

Schutte, Meyer & Co., G.m.b.H., Letmathe, Westphalia, Germany. (*Small castings*) (DORTMUND)

Seo Koatsu Kogyo Co., Ltd., Osaka, Japan. (*Small forgings*) (KOBE)

Sharon Steel Corporation, Roemer Works, Farrell, Pa., U.S.A. (*Ingots, blooms, billets, narrow plates and sections*) (CLEVELAND)

Shimizu Forge Co., Ltd., Tokyo, Japan. (*Forgings*) (YOKOHAMA)

Shin Nippon Tanko K.K., Kawasaki, Japan. (*Small forgings*) (YOKOHAMA)

Shun Fung Ironworks Ltd., Kowloon, Hong Kong. (*Castings*) (HONG KONG)

Siderurgia Nacional, S.a.r.l., Seixal, Portugal. (*Sections and bars*) (LISBON)

Siderurgica Ebroacero S.A., Zaragoza, Spain. (*Castings*) (BILBAO)

S.I.F.E.M.A. S.A., Bilbao, Spain. (*Steel castings*) (BILBAO)

S.I.S.M.A. — Società Industrie Siderurgiche Meccaniche & Affini, Villadossola (Novara), Italy. (*Rolled bars and rivets*) (MILAN)

SKF. Stål Hofors Bruk, Hofors, Sweden. (*Billets, bars and forgings, and thick walled tubes*) (STOCKHOLM)

Škoda, Oborový Podnik, Plzeň, Czechoslovakia. (*Castings and forgings*) (VIENNA)

Smedjebackens Valsverks Aktiebolag, Smedjebacken, Sweden. (*Bars, sections and ingots for re-rolling*)

Société Anonyme d'Exploitation des Aciéries de Bordeaux, Pessac, Gironde, France. (*Castings*) (BORDEAUX)

Société Lorraine de Laminage Continu, Sollac, B.P.11, Florange, Moselle, France. (*Ingots, slabs and plates*) (SAAR)

Société Métallurgique de Normandie, Mondeville, France. (*Ingots, blooms, billets and bars*) (ROUEN)

Société Mosellane de Siderurgie, Hagondange (Moselle), France. (*Blooms, billets, bars and sections*) (SAAR)

Sollinger Hütte G.m.b.H., Uslar/Solling, Germany. (*Castings*) (HANNOVER)

Sorel Industries, Ltd., Sorel, P.Q., Canada. (*Ingots and forgings*) (MONTREAL)

South African Iron & Steel Industrial Corporation, Ltd., "Iscor" Works, Pretoria, Transvaal, S. Africa. (*Ingots, billets and sections*) (VEREENIGING)
"Iscor" Works, Vanderbijlpark, Transvaal, S. Africa. (*Ingots, billets, slabs and plates*) (VEREENIGING)

Staalgietwerk SMDK, N.V. Utrecht. (*Ingots and castings*) (AMSTERDAM)

Stahl-u. Röhrenwerke Reisholz G.m.b.H., Germany.
Works at Reisholz. (*Ingots and seamless tubes*)
Works at Oberbilk. (*Forgings*) (DUSSELDORF)

Stahlwerk Mannheim A.G., Mannheim-Rheinau, Germany. (*Castings*) (MANNHEIM)

Stahlwerk Südwestfalen, A.G.
Werk Geisweid, Geisweid Kreis Siegen, Germany. (*Ingots, bars, billets, thin plates, sheets and coils*) (COLOGNE)
Werksgruppe Hagen, Werk Wehringhausen, Hagen, Germany. (*Ingots, bars and forgings*) (DORTMUND)

Stahlwerke Bochum A.G., Bochum, Germany. (*Castings, rolled materials and plates*) (DUSSELDORF)

Standard Steel Division of Baldwin-Lima-Hamilton Corp., Burnham, Pa., U.S.A. (*Forgings*) (PHILADELPHIA)

Stavanger Staal A.S., Jørpeland, near Stavanger, Norway. (*Castings*) (BERGEN)

Steel Company of Australia, Pty. Ltd., Coburg, Melbourne, Australia. (*Castings*) (MELBOURNE)

Steel Company of Canada, Hamilton, Ontario, Canada.
Works: Hamilton. (*Bars and angles, plates and billets*) (TORONTO)
Works: Montreal. (*Bars, angles, plates and billets*) (MONTREAL)

Steelplast, S.A., La Louvière, Belgium. (*Small castings*) (ANTWERP)

Steirische Gusstahlwerke, A.G., Vienna. *Works:* Judenburg, Styria, Austria. (*Forgings and bars*) (VIENNA)

Stenberg, John, Oy-AB, Helsingfors, Finland. (*Small castings*) (HELSINKI/HELSINGFORS)

Stora Kopparbergs Bergslags A/B, Specialstalverken, Vikmanshyttan, Sweden. (*Forgings, bars and sections*) (STOCKHOLM)

Stora Kopparbergs Bergslags Aktiebolag, Falun, Sweden.
Works: Domnarfvet. (*Ingots, sections and plates*) (STOCKHOLM)
Works: Söderfors. (*Forgings, bars and sections*) (STOCKHOLM)

Stork-Volma N.V., Gorredijk, Holland. (*Small castings*) (HAREN-GRONINGEN)

Stramezzi, P., & C., Acciaieria e Ferriera di Crema, Crema, Italy. (*Ingots, bars, small sections and rivets*) (MILAN)

Streicher, M., Asperg/Württ, near Stuttgart, Germany. (*Castings*) (STUTTGART)

Stridsberg & Biorck, A.B., Trollhattan, Sweden. (*Castings*) (GOTHENBURG)

Strömmen Staal A/S, Norway.
Works: Raufoss. (*Castings*) (OSLO)
Strommen. (*Castings*) (OSLO)

Sucesora de Aceros Electricos S.A., Barcelona, Spain. (*Castings*) (BARCELONA)

Sud Ouest, Société des Forges et Aciéries du, Bordeaux (Gironde), France. (*Castings and forgings*) (BORDEAUX)

Sulzer Bros. Ltd., Winterthur, Switzerland. (*Castings and forgings*) (WINTERTHUR)

Sumitomo Electric Industries, Ltd., Itami Works, Itami, Hyogo Prefecture, Japan. (*Ingots and small bars*) (KOBE)

Sumitomo Metal Industries, Ltd.
Kokura Steel Works, Kitakyushu-City, Japan. (*Ingots, billets, bars and sections*) (SHIMONOSEKI)
Osaka Steel Works, Osaka. (*Castings, forgings and bars*) (KOBE)
Steel Tube Works, Amagasaki, Japan. (*Ingots, forgings, small bars, sections and weldless tubes.*) (KOBE)
Wakayama Steel Works, Wakayama, Japan. (*Ingots, plates, seamless tubes and electric resistance welded tubes*) (KOBE)

Sumitomo Shipbuilding & Machinery Co., Ltd.
Niihama Works, Niihama, Japan. (*Castings*) (KOBE)
Tamashima Works, Tamashima, Japan. (*Castings*) (KOBE)

Sunnan Iron Works Co., Ltd., Yaizu, Japan. (*Forgings*) (YOKOHAMA)

Surahammars Bruks Aktiebolag, Surahammar, Sweden. (*Plates, forgings and castings*) (STOCKHOLM)

Svenska Jarnvagsverkstaderna, A/B, Linköping, Sweden. (*Castings*) (STOCKHOLM)

Svenska Kullagerfabriken, A/B.
Works: Katrineholm, Sweden. (*Castings*) (STOCKHOLM)
Works: Hellefors Jernverk, Hällefors, Sweden. (*Ingots and bars*) (GOTHENBURG)

Švermové Železiarné, Narodny Podnik (Sverma's Iron Works, National Corporation), Podbrezová, Czechoslovakia. (*Ingots, and plates*) (VIENNA)

Sydney Steel Corporation, Sydney, N.S., Canada. (*Ingots, billets and sections*) (HALIFAX, N.S.)

Takada Steel Works, Ltd., Takada City, Nara Prefecture, Japan. (*Castings*) (KOBE)

Takasaki Metal Industry Co., Ltd., Takasaki Plant, Takasaki, Japan. (*Small castings*) (YOKOHAMA)

Talleres de Moreda, S.A., Gijon. (*Forgings*) (GIJON)

Tamaris, Société des Ateliers et Fonderies de, Tamaris (Gard), France. (*Castings*) (MARSEILLES)

Tata Engineering & Locomotive Co., Ltd., Jamshedpur 4, India. (*Castings*) (CALCUTTA)

Tata Iron & Steel Co., Ltd., Jamshedpur, India. (*Blooms, billets, bars, plates and sections*) (CALCUTTA)

Teikoku Chokosho Co., Ltd., Osaka, Japan. (*Castings*) (KOBE)

Temple, Acieries du, Saint-Michel de Maurienne, (Savoie) France. (*Rolled and forged bars and billets*) (LYONS)

Tennessee Coal & Iron Division, United States Steel Corporation, Birmingham, Ala., U.S.A. *Works:* Ensley, Ala. *Rolling mills, also forgings:* Bessemer and Fairfield, Ala. (MOBILE)

"Terni" Società per l'Industria e l'Elettricità. *Works:* Terni, Italy. (*Ingots, forgings, castings and plates*) (NAPLES)

Titovi Zavodi Litostroj, Ljubljana, Yugoslavia. (*Castings*) (SPLIT)

Tohoku Special Steel Works Ltd., Sendai, Japan. (*Ingots, small forgings, billets and bars*) (YOKOHAMA)

Tokai Special Steel Co., Ltd., Nagoya, Japan. (*Ingots*) (KOBE)

Tokushu Seiko (Special Steel Mfg.) Co., Ltd., Kawasaki Works, Kawasaki, Japan. (*Ingots, forgings and bars*) (YOKOHAMA)

Tokyo Kikai Kabushiki Kaisha, Oshima Cast Steel Works, Tokyo, Japan. (*Castings*) (YOKOHAMA)

Tokyo Precision Forging Works Co., Ltd. (Tokyo Seitan Works Co., Ltd.), Ichikawa City, Chiba Prefecture, Japan. (*Small forgings*) (YOKOHAMA)

Tokyo Steel Casting Co., Ltd., Tokyo, Japan. (*Castings*) (YOKOHAMA)

Tokyo Tankosho Co., Ltd., Kawasaki Factory, Kawasaki, Japan. (*Small forgings*) (YOKOHAMA)

Topy Industries Ltd.,
Tokyo Works, Tokyo, Japan. (*Sections*) (YOKOHAMA)
Toyohashi Works, Toyohashi, Japan. (*Ingots, sections and flat bars*) (KOBE)

Toshiba Steel Co., Ltd., Tokyo, Japan. (*Sections and ingots for forging and plates*) (YOKOHAMA)

Tosi, Franco, Società per Azioni, Legnano, Italy. (*Forgings and castings*) (MILAN)

Toyo Kikai-Kinzoku Co. Ltd., Tsuchiyama Plant, Akashi, Japan. (*Small castings and small forgings*) (KOBE)

Třinecké železárny velké Rijnové socialistické revoluce, národni podnik (Třinec Iron Works Great-Socialistic October Revolution National Corporation), Třinec, Czechoslovakia. (*Ingots, sections, bars and castings*) (VIENNA)

Trubia, Fábrica Nacional de, Trubia Asturias, Spain. (*Castings and forgings*) (GIJON)

Turkiye Demir ve Celik Isletmeleri, Karabuk, Turkey (*Ingots, thin plates, rolled sections and bars*) (ISTANBUL)

Tvornica Dizalica I. Ljevaonica "Vulkan", Rijeka II, Yugoslavia. (*Castings*) (RIJEKA)

Tweer, Reinhard, G.m.b.H., Sennestadt/Westf., Germany. *Works:* Sennestadt. (*Castings*) (HANNOVER)

Ube Industries, Ltd., Ube Machinery Works, Ube, Japan. (*Ingots, forgings and castings*) (SHIMONOSEKI)

Uddeholms Aktiebolag, Uddeholm, Sweden.
Works: Degerfors. (*Ingots, plates, sections and bars*) (GOTHENBURG)
Works: Hagfors, (*Castings, ingots, forgings, bars and sections*) (GOTHENBURG)
Works: Nykroppa. (*Ingots*) (GOTHENBURG)
Works: Storfors. (*Seamless tubes*) (GOTHENBURG)

Ugine Kuhlmann, Savoie, France. (*Ingots, billets, bars, sections, castings and forgings.* (MARSEILLES)

União Fabril, Companhia, Barreiro, Portugal. (*Castings*) (LISBON)

Union de Siderurgicas, Asturianas, S.A. (UNINSA).
Fabrica de Mieres, Asturias, Spain. (*Sections, bars and plates up to* 15 *mm. in thickness*) (GIJON)
Fabrica de Gijon, Gijon, Spain. (*Rivet bars and castings*) (GIJON)

Factoria de La Felguera, La Felguera, Asturias, Spain. (*Ingots, billets, plates and sections*) (GIJON)

Union des Aciéries, Société Anonyme, Marcinelle, Charleroi, Belgium. (*Castings*) (ANTWERP)

Union Sidérurgique Lorraine, SIDELOR.
Usine d'Homécourt, Meurthe et Moselle, France. (*Ingots, blooms, billets, narrow plates and universal flats*) (SAAR)
Usine de Rombas, Moselle, France. (*Ingots, blooms, billets, bars and sections*) (SAAR)

Union Sidérurgique du Nord et de l'Est de la France, "USINOR".
Usine de Dunkerque, Dunkerque (Nord). (*Ingots and plates*) (DUNKERQUE)

GROUPE A.
Usines de Denain, Denain (Nord). (*Ingots, plates, sections and castings*) (VALENCIENNES)

GROUPE B.
Usines de Valenciennes, Valenciennes (Nord). (*Ingots, forgings, blooms, bars and sections*) (VALENCIENNES)

GROUPE C.
Usine de Longwy (Meurthe et Moselle), France. (SAAR)
Section Mont Saint Martin. (*Sections and plates*)
Section Senelle. (*Ingots, blooms, bars and sections*)
Usine de Thionville, Thionville (Moselle), France. (*Forgings and castings*) (SAAR)

Union Steel Corporation of South Africa, Ltd. (Usco).
Works: Vereeniging, Transvaal, South Africa. (*Ingots, billets, small sections, castings and rivet bars*) (VEREENIGING)

United States Steel Corporation, Pittsburgh, Pa., U.S.A.
Clairton Works, Clairton, Pa. (*Ingots, blooms, bars and sections*) (CLEVELAND, O.)
Duquesne Works, Duquesne, Pa. (*Ingots, billets, blooms and bars*) (CLEVELAND, O.)
Fairless Works, Fairless Hills, Pa. (*Thin plates, bars and sections*) (PHILADELPHIA)
Gary Works, Gary, Ind. (*Billets, blooms, plates, sections, bars and forgings*) (CHICAGO)
Geneva Works, Provo, Utah. (*Plates*) (LOS ANGELES)
Homestead District Works, Pa., including McKees Rock Works. (*Ingots, billets, blooms, slabs, plates, sections and forgings*) (CLEVELAND, O.)
Irvin Works, Dravosburg, Pa. (*Rolling mills for thin plates*) (CLEVELAND, O.)
McDonald Mills, Youngstown. (*Rolling mills for bars and sections*) (CLEVELAND, O.)
Ohio Works, Youngstown. (*Ingots, billets and blooms*) (CLEVELAND, O.)
South Works, South Chicago, Ill. (*Plates, sections and bars*) (CHICAGO)
Torrance Works, Torrance, Calif. (*Round bars and sections*) (LOS ANGELES)

Usinas Siderurgicas de Minas Gerais S.A., Belo Horizonte, Estado de Minas Gerais, Brazil.
Works: Ipatinga, Estado de Minas Gerais. (*Ingots, slabs and plates*) (RIO DE JANEIRO)

Válcovny Trub a Železarny, Narodni Podnik, (Tube Rolling Mills and Iron Works, National Corporation), Chomutov, Czechoslovakia.
Works: Železárny Bílá Cerkev, Narodni Podnik, Hrádek u Rokycan. (*Ingots and bars*) (VIENNA)
Works: Chomutov. (*Seamless steel tubes*) (VIENNA)

VALLOUREC.
Usine d'Anzin-Anzin (Nord), France. (*Weldless rolled or drawn tubes*) (VALENCIENNES)
Usine d'Aulnoye, Aulnoye (Nord), France. (*Weldless rolled and drawn tubes*) (VALENCIENNES)

Varde Staalvaerk, Varde, Denmark. (*Ingots and castings*) (ODENSE)

VEB Magdeburger Armaturenwerke, "Karl Marx", Magdeburg, Germany. (*Castings*) (BERLIN)

VEB Maschinenfabrik und Eisengiesserei Dessau, Dessau, Germany. (*Castings*) (BERLIN)

VEB Schwermaschinenbau-Kombinat "Ernst Thalman", Magdeburg-Buckau, Germany. (*Ingots and forgings*) (BERLIN)

VEB Qualitats - und Edelstahl - Kombinat Stahl - und Walzwerk Groditz, 8402 Groditz, Germany. (*Forgings and castings*) (Berlin)

Vecor Heavy Engineering, Ltd., Vanderbijlpark, Transvaal, South Africa. (*Castings*) (VEREENIGING)

Vereinigte Oesterreichische Eisen-und-Stahlwerke, A.G.

Works: Liezen, Styria. (*Ingots for forgings, castings*) (VIENNA)

Works: Linz a.d. Donau, Upper Austria. (*Plates, forgings and castings*) (VIENNA)

Vickers Ruwolt Pty., Ltd., Richmond, Melbourne, Australia. (*Steel castings and ingots*) (MELBOURNE)

Victoria Machinery Depot Co., Ltd., Victoria, B.C., Canada. (*Castings*) (VANCOUVER)

Villa, Giovanni, S.p.A., Officine Meccaniche-Fucinati-Stampati, Milan, Italy. (*Forgings*) (MILAN)

Viomichania Chalyvon Ltd., Athens, Greece. (*Castings*) (PIRÆUS)

Vitkovické Železárny Klementa Gottwalda, národni podnik (The Vitkovice Steel Works Klement Gottwald, National Corporation), Ostrava 10, Czechoslovakia. (*Castings, forgings, plates, sections, bars and seamless tubes*) (VIENNA)

Vizcaya, Altos Hornos de, S.A., Fabrica de Sagunto, Sagunto, Spain. (*Ingots, plates, bars and sections*) (VALENCIA)

Vizcaya, Sociedad Altos Hornos de, Bilbao, Spain. (*Ingots, bars, sections, forgings and plates up to* 10 *mm thick*) (BILBAO)

Von Roll A.-G., Gerlafingen, Switzerland. (*Ingots, round bars and forgings*) (WINTERTHUR)

Vuoksenniska Oy Aktiebolag, Imatra Steel Works, Imatra, Finland. (*Ingots, slabs, blooms and billets, bars, sections and castings*) (HELSINKI HELSINGFORS)

Waagner-Biro Aktiengesellschaft, Vienna, Austria.

Works: Werk C, Vienna. (*Castings*) (VIENNA)

Wakamatsu Sharyo Co., Ltd., Kitakyushu-City, Japan. (*Small castings*) (SHIMONOSEKI)

Walkers Ltd., Maryborough, Queensland, Australia. (*Forgings and castings*) (BRISBANE)

Wartsila Oy. A/B, Steel Mill, Dalsbruk, Finland. (*Ingots, billets, bars, castings and forgings*) (ÅBO)

Washington Iron Works, Seattle, Wash., U.S.A. (*Castings*) (SEATTLE)

Wasino Machine Co., Ltd.,

Imamura Plant, Anjo Aichi Prefecture, Japan. (*Castings*) (KOBE)

Komaki Plant, Komaki Aichi Prefecture, Japan. (*Small castings*) (KOBE)

Watanabe Steel Works Co., Ltd., Tokyo, Japan. (*Castings*) (YOKOHAMA)

Welmet Industries Ltd., Welland, Ontario, Canada. (*Castings*) (TORONTO)

Wendel-Sidelor, Usine de Micheville, Villerupt, Meurthe et Moselle, France. (*Ingots, blooms, billets, bars and sections*) (SAAR)

Western Canada Steel Ltd., (Vancouver Rolling Mills Ltd.,) Vancouver, B.C., Canada. (*Sections and bars*) (VANCOUVER)

Wittener Hutte Aktiengesellschaft Witten, Ruhr, Germany. (*Castings*) (DORTMUND)

Wood, Alan, Steel Company, Conshohocken, Pa., U.S.A. (*Blooms, billets and plates*) (PHILADELPHIA)

Wurth, Société Anonyme des Anciens Etablissements Paul, Luxembourg. (*Castings*) (SAAR)

Yamato Kogyo Co., Ltd., Himeji, Japan. (*Castings*) (KOBE)

Yamato Steel Works, Ltd., Osaka, Japan. (*Ingots, sections and plates*) (KOBE)

Yonago Steel Works, Ltd., Yonago, Japan. (*Castings*) (KOBE)

Youngstown Sheet and Tube Company.

Brier Hill Works, Youngstown, Ohio, U.S.A.

Campbell Works, Campbell, Mahoning Co., Ohio, U.S.A. (*Ingots, and plates up to* 12,5 *mm in thickness*) (PITTSBURGH)

Zaklady Mechaniczne Im. Gen. K. Swierczewskiego, Elblag, Poland. (*Castings*) (GDANSK)

Zaklady Metalurgiczne, Poznan, "Pomet" Poznan, ul Krancowa 15, Poland. (*Castings*) (GDANSK)

Zaklady Urzadzen Chemicznych i Armatury Przemyslowej, Kielce, Poland. (*Castings*) (KATOWICE)

Zaklady Urzadzen Technicznych "Zgoda", Swietochlowice, Poland. (*Forgings*) (KATOWICE)

Zelezarna Jesenice, Jesenice, Yugoslavia. (*Plates, bars, sections and castings*) (SPLIT)

Zelezarna Ravne, Ravne na Koroskem, Yugoslavia. (*Castings, forgings, billets and bars*) (RIJEKA)

Zelezárny a drátovny Bohumin, národni podnik (Iron Works and Wire Works Bohumin, National Corporation), Bohumin, Czechoslovakia. (*Small sections and bars*) (VIENNA)

Zeljezara "Boris Kidric", Niksic, Yugoslavia. (*Plates and castings*) (SPLIT)

Zeljezara Sisak, Sisak-Predgradje, Yugoslavia. (*Seamless tubes*) (RIJEKA)

FIRMS IN COUNTRIES OTHER THAN GREAT BRITAIN AND IRELAND (ARRANGED ACCORDING TO SURVEYING DISTRICTS)

Aalborg

Frichs A/S, Aarhus, Denmark. (*Castings*)

Åbo

Ky Åminnefors Kb, Åminnefors Stålverk, Åminnefors, Finland. (*Ingots, billets, bars and sections*)

Lokomo Oy, Tampere, Finland. (*Ingots, forgings and castings*)

Raahe Oy, Raahe, Finland. (*Small castings*)

Rautaruukki Oy, Raahe, Finland. (*Ingots and plates*)

Rosenlew, Oy W., Ab, Porin Konepaja, Pori, Finland. (*Small castings*)

Salon Sahko- Ja Konetehdas Oy, Salo, Finland. (*Small castings*)

Wärtsilä Oy, AB., Steel Mill, Dalsbruk, Finland. (*Ingots, billets, bars, forgings and castings*)

Adelaide

Bradford Kendall Ltd., Adelaide, South Australia. (*Castings*)

Mason & Cox Pty. Ltd., Adelaide, S. Australia. (*Castings*)

Alexandria

Egyptian Iron & Steel Co., S.A.E., Helwan, U.A.R. (*Plates*)

Amsterdam

Dikkers, G., & Co., N.V., Hengelo, Holland. (*Small castings*)

Koninklijke Demka Staalfabrieken, N.V., Utrecht, Holland. (*Rolling mill for bars*)

Koninklijke Nederlandsche Hoogovens & Staalfabrieken N.V. (Royal Netherlands Blast-Furnaces & Steel Works, Ltd.), Ymuiden, Holland. (*Plates and sections*)

Staalgietwerk SMDK, N.V., Utrecht, Holland. (*Ingots and castings*)

Antwerp

Allard, Usines & Aciéries, Société Anonyme, Mont-sur-Marchienne, near Charleroi. (*Castings*)

Allard, Usines & Aciéries, Société Anonyme, Turnhout. (*Small castings*)

Baume, Société Anonyme des Forges et Laminoirs de, Haine St. Pierre. (*Ingots, bars and sections*)

Boël, Usines Gustave, Soc. An., La Louvière. (*Ingots, forgings, castings, plates and universal flats*)

Boom, Travaux Métalliques de, Société Anonyme, Boom. (*Small castings*)

Charleroi, Société Anonyme de la Fabrique de Fer de, Charleroi. (*Ingots, slabs and plates*)

Antwerp—*continued*

Clabecq, Société Anonyme Forges de, Clabecq, Belgium. (*Ingots, plates, bars and sections*)

Cockerill-Ougrée-Providence, S.A., Seraing, Belgium.
- *Group A Works:* Division Centre Ougrée. (*Ingots, blooms, billets, slabs and thin plates*)
- Division Ouest, Seraing. (*Ingots, blooms, billets, slabs, castings and forgings*)
- *Group B Works:* Marchienne-au-Pont. (*Sections, bars, ingots and blooms*)

Compagnie Générale des Aciers, Société Anonyme, Thy-le-Château, Belgium. (*Castings*)

Esperance Longdoz S.A., Liége, Belgium. (*Ingots and thin plates*)

Hainaut-Sambre, Société Métallurgiques, S.A., Couillet.
- Division de Couillet. (*Ingots, blooms, bars, forgings and castings*)
- Division de Montignies et Chatelinlau. (*Rolling mill*)

Haine St. Pierre et Lesquin, Aciéries de, Société Anonyme, Haine St. Pierre. (*Castings*)

Henricot, Usines Emile, Court St. Etienne. (*Castings*)

Jadot, Société Anonyme Etablissements, Beloeil, Belgium. (*Small castings*)

Jemappes, Société Anonyme Forges et Laminoirs de, Jemappes, near Mons, Belgium. (*Ingots, blooms and bars*)

Leonard-Giot, Société Anonyme Usines & Aciéries Marchienne-au-Pont. (*Castings*)

Meuse, Les Aciéries de la, S.A., Cheratte-lez-Liege, Belgium. (*Castings*)

Meuse, Les Usines à Tubes de la, Flémalle-Haute, Belgium. (*Seamless tubes*)

Steelplast, S.A. La Louvière, Belgium. (*Small castings*)

Union des Aciéries, Société Anonyme, Marcinelle, Charleroi. (*Castings*)

Augsburg

Decker, Gebrüder, Betrieb 1, Eisen- & Stahlgiesserei, Nürnberg 2, Ostendstr. 84. (*Electric steel castings*)

Krauss-Maffei, A.G., München-Allach, Germany. (*Castings*)

Maximilianshütte, Eisenwerk-Gesellschaft m.b.H., Sulzbach-Rosenberg, Bavaria, Germany, Haidhof Works. (*Ingots, billets, bars, small sections and thin plates*)

Baltimore, Md.

Bethlehem Steel Co., Sparrows Point, Md., U.S.A. (*Plates*)

Barcelona

Funderia S.A. de, Manresa, Spain. (*Castings*)

Hierros y Aceros Industriales S.A., San Adrian de Besos, Barcelona, Spain. (*Small castings*)

Industrias del Besos, S.A., Barcelona, Spain. (*Small sections and bars*)

Industrias Mecanicas, Sociedad Anonimà, Barcelona, Spain. (*Castings*)

Material y Construcciones S.A., Barcelona, Spain. (*Castings*)

Sucesora de Aceros Electricos S.A., Barcelona, Spain. (*Castings*)

Bergen

Stavanger Staal A.S., Jorpeland, near Stavanger, Norway. (*Castings*)

Berlin

Borsig A.G., Berlin-Tegel, Germany. (*Ingots, forgings and castings*)

VEB Magdeburger Armaturenwerke "Karl Marx", Magdeburg, Germany. (*Castings*)

VEB Maschinenfabrik und Eisengiesserei Dessau, Dessau, Germany. (*Castings*)

VEB Qualitats-und Edelstahl-Kombinat, Stahl-und Walzwerk Groditz, 8402 Groditz, Germany. (*Forgings and castings*)

VEB Schwermaschinenbau-Kombinat "Ernst Thalmann", Magdeburg-Buckau, Germany. (*Ingots and forgings*)

Bilbao

Acerias y Forjas de Azciotia, Azciotia Juipuzcoa, Spain. (*Ingots and small rolled bars*)

Aceros y Fundiciones del Norte Pedro Orbegozo y Cia. S.A., Hernani (Guipuzcoa), Spain. (*Ingots, forgings and rolled bars*)

Agrometal S.A., Miranda de Ebro Works, Bilbao, Spain. (*Castings*)

Amurrio, S.A., Talleres de, Amurrio, Alava, Spain. (*Steel castings*)

ARANZABAL S.A., Victoria Alava, Spain. (*Small castings*)

Babcock & Wilcox, Sociedad Española de Construcciones.
Head Office: Calle Ercilla 1, Bilbao.
Works: Galindo-San Salvador del Valle. (Vizcaya) (*Castings, ingots and forgings*)

Basconia, Compañia Anonima, Bilbao, Spain. (*Plates, sections and bars*)

Compañia Auxiliar de Ferrocarriles, Beasain, Guipuzcoa, Spain. (*Small castings and forgings*)

Cooperativa Industrial Electrodos y Aceros, Boó, Santander, Spain. (*Castings*)

Crane-Fisa S.A., Bilbao, Spain. (*Small castings*)

Deusto, S.A. Talleres de, Luchana, Bilbao, Spain. (*Ingots, castings and small forgings*)

Echevarria, Sociedad Anonima, Bilbao, Spain. (*Small sections and bars, small forgings and ingots*)

Bilbao—*continued*

Echeverria, Patricio, S.A., Legazpia, Spain. (*Ingots, blooms, forgings and small bars*)

Eguiluz, Talleres, Miranda del Ebro, Burgos, Spain. (*Castings*)

Espanoles, Astilleros, S.A., Factoria de Reinosa, Spain. (*Ingots, forgings, castings, plates and sections*)
Factoria de Sestao. (*Small castings, ingots and forgings*)

Euskalduna, Compania, Fundicion de Asua, (Near Bilbao) Vizcaya, Spain. (*Castings*)

Ferretera Montanesa S.A., Torrelavega, Spain. (*Castings*)

Forjas Alavesas, S.A., Vitoria, Spain. (*Ingots, rolled bars and forgings*)

Fundiciones del Estanda S.A., Beasain, Spain. (*Castings*)

Fundiciones Echevarria S.A., Beasain, Guipuzcoa, (*Ingots, small rolled bars and castings*)

Fundiciones Especiales Zaragoza S.A., Zaragoza, Spain. (*Castings*)

Llodio, Aceros de, Ltda., Llodio, near Bilbao, Spain. (*Castings, ingots, forgings and rolled bars*)

Luzuriaga, Victorio, S.A., Pasajes, Guipuzcoa, Spain.
Works: Lasarte, Nr. San Sebastian, Guipuzcoa. (*Castings*)

Nueva Montana Quijano S.A., Nueva Montana, Santander, Spain. (*Castings*)

Olarra S.A.
Works: Erandio, Bilbao, Spain. (*Ingots and small bars*)
Works: Larrendo, Lujna, Vizcaya, Spain. (*Ingots and rolled bars*)

Siderurgica Ebroacero S.A., Zaragoza, Spain. (*Castings*)

Sifema S.A. Bilbao. (*Steel castings*)

Vizcaya, Sociedad Altos Hornos de, Bilbao, Spain. (*Ingots, bars, sections, forgings and plates up to 10 mm thick*)

Bombay

Mukand Iron & Steel Works, Ltd., Kurla, Bombay 70, India. (*Castings*)

Bordeaux

Société Anonyme d'Exploitation des Aciéries de Bordeaux, Pessac, Gironde, France. (*Castings*)

Sud Ouest, Société des Forges et Aciéries du, Bordeaux (Gironde). France. (*Castings and forgings*)

Bremen

Bremer Vulkan, Schiffbau und Maschinenfabrik, Bremen-Vegesack, Germany. (*Castings*)

Klöckner-Werke A.G., Hutte Bremen, Germany. (*Plates*)

Brisbane

Bradford Kendall Ltd., Runcorn, Brisbane, Queensland. (*Castings*)

Walkers Ltd., Maryborough, Queensland, Australia. (*Forgings and castings*)

Buenos Aires

Aceria Bragado S.A.I.C., Bragado, Argentina. (*Castings*)

Astilleros Rio Santiago, Ensenada, Buenos Aires, Argentina. (*Steel castings*)

Herchamet S.A.I.C., Fundicion Electrica de Aceros, Velez Sarfield, Rosario, Argentina. (*Castings*)

Marathon Argentina, Aceros Finos y Especiales S.A., Vilia Constiticion, Santa Fe, Argentina. (*Ingots, forgings and forged bars*)

Calcutta

Bhartia Electric Steel Co., Ltd., Calcutta, India. (*Castings*)

Burn & Co., Ltd., Howrah, India. (*Castings*)

Electrosteel Castings Ltd., Khardah, West Bengal, India. (*Castings*)

Hindustan Steel Ltd.,

Rourkela, Orissa, India. (*Ingots, slabs and plates*)

Durgapur Steel Plant, West Bengal, India. (*Blooms, billets, bars and sections*)

Bhilai Steel Project, Bhilai, Madhya Pradesh, India. (*Ingots, blooms, billets and sections*)

Indian Iron & Steel Co., Ltd.,

Burnpur Works, Burnpur, West Bengal, India. (*Sections and angles*)

Kulti Iron Works, Kulti, India. (*Castings*)

Indian Tube Company, Ltd., Jamshedpur, India. (*Seamless tubes*)

Kumardhubi Engineering Works Ltd., P.O. Box Kumardhubi Dist. Dhanbad (Bihar), India. (*Castings*)

Metal & Steel Factory, Ishapore, West Bengal, India. (*Ingots, blooms, billets, forgings, castings and bars*)

National Iron & Steel Co., Ltd., Stephen House, Calcutta, 1, India. (*Castings*)

Tata Engineering & Locomotive Co., Ltd., Jamshedpur 4, India. (*Castings*)

Tata Iron & Steel Co., Ltd., Jamshedpur, India. (*Blooms, billets, bars, plates and sections*)

Chicago

Bethlehem Steel Co., Burns Harbour Plant, Chesterton, Indiana, U.S.A. (*Rolling mill for plates*)

Colorado Fuel & Iron Corporation, Minnequa Works, Pueblo, Colorado, U.S.A., (*Ingots, bars and small sections*)

Falk Corporation, Milwaukee, Wis., U.S.A. (*Castings*)

Finkl, A., & Sons Company, Chicago, Illinois, U.S.A. (*Forgings*)

Granite City Steel Co., Granite City, Illinois, U.S.A.

Inland Steel Co., Indiana Harbour, Indiana, U.S.A. (*Ingots, blooms, billets and slabs*)

Republic Steel Corporation, Chicago Plant, Chicago, Illinois, U.S.A.

Works: 118th Street, Chicago Rolling Mills, East Chicago, Ind., (*Angles and bars*)

Chicago—*continued*

U.S. Steel Co., Pittsburgh, Pa., U.S.A.

Gary Works, Gary Ind. (*Billets, blooms, plates, sections, bars and forgings*)

South Works, South Chicago, Illinois, (*Plates, sections and bars*)

Cleveland, O.

American Rolling Mill Co., Middletown, O., U.S.A. (*Castings and forgings*)

Bethlehem Steel Corp.

Johnstown Plant, Johnstown, Pa., U.S.A. (*Ingots, billets, slabs, plates and bars*)

Lackawanna, N.Y., U.S.A. (*Ingots, blooms, billets, bars, plates and sections*)

Crucible Steel Corporation, Midland Division, P.O. Box 226, Midland, Pa. 1505g., U.S.A. (*Ingots, slabs, billets, hot rolled and cold drawn bars*)

Edgewater Corporation, Oakmont, Pennsylvania, U.S.A. (*Ingots and forgings*)

Great Lakes Steel Corporation, Division of National Steel Corporation, Ecorse, Detroit 29, Michigan, U.S.A. (*Ingots, billets, bars, slabs, plate, blooms, sheet and coiled strip*)

Jones & Laughlin Steel Corporation, Pittsburgh, Pa., U.S.A.

Latrobe Forge & Spring, Inc., Latrobe, Pa. (*Ingots and forgings*)

National Forge Co.

Erie Division, Erie, Pennsylvania, U.S.A. (*Ingots, forgings and castings*)

Irvine, Warren County, Pennsylvania, U.S.A. (*Ingots and forgings*)

Ohio Steel Foundry Co., Lima, Ohio, U.S.A. (*Ingots, forgings and castings*)

Pittsburgh Steel Company, Pittsburgh 30, Pa., U.S.A.

Works: Monessen, Pa. (*Ingots, billets and slabs*)

Works: Allenport, Pa. (*Rolling mills*)

Republic Steel Corporation, Cleveland, O., U.S.A.

Buffalo Plant, Buffalo, N.Y., U.S.A.

Central Alloy District, Massillon Plant, Massillon, O., U.S.A.

Cleveland District, Cleveland, O., U.S.A.

Corrigan McKinney Plant. (*Ingots, blooms and billets*)

Upson Nut Plant. (*Round and square bars*)

Youngstown District, Youngstown, O., U.S.A.

Sharon Steel Corporation, Roemer Works, Farrell, Pa., U.S.A., (*Ingots, blooms, billets, narrow plates and sections*)

United States Steel Corporation, Pittsburgh, Pa., U.S.A.

Clairton Works, Clairton, Pa. (*Ingots, blooms, bars and sections*)

Duquesne Works, Duquesne, Pa. (*Ingots, billets, blooms and bars*)

Cleveland O.—*continued*

United States Steel Corporation—*continued*

Homestead District Works, Pa., (including McKees Rock Works.) (*Ingots, billets, blooms, slabs, plates, sections and forgings*)

Irvin Works, Dravosburg, Pa. (*Rolling mills for thin plates*)

McDonald Mills, Youngstown. (*Rolling mills for bars and sections*)

Ohio Works, Youngstown. (*Ingots, billets and blooms*)

Youngstown Sheet and Tube Company, Brier Hill Works, Youngstown, Ohio, U.S.A.

Campbell Works, Campbell, Mahoning Co., Ohio. (*Ingots and plates up to 12,5 mm in thickness*)

Cologne (Köln)

Boschgotthardshütte, Otto Breyer G.m.b.H., Edelstahlwerk-Press. u. Hammerwerk-Mechanische Werkstätten, Hüttental-Weidenau, Germany. (*Ingots and forgings*)

Breitenbach, Ed., G.m.b.H., Hüttental-Weidenau/Sieg, Germany. (*Castings*)

Edelstahlwerke Buderus A.G., Wetzlar, Germany. (*Ingots, blooms, billets, bars, forgings and plates*)

Eschweiler Bergwerks-Verein Hüttenbetriebe, Eschweiler-Aue, Germany. (*Ingots and seamless tubes*)

Gussstahlwerke Risch K.G., Bergisch-Gladbach, Germany. (*Electric steel castings*)

Hüttenwerke Siegerland A.G., Niederschelden, Germany. (*Ingots and slabs*)

Klockner-Werke A.G., Mannstaedt-Werke, Troisdorf, Germany. (*Rolling mills for sections*)

Schmidt & Clemens, Edelstahlwerk, Kaiserau b/Engelskirchen Bez. Köln, Germany. (*Ingots, forgings, castings and bars*)

Stahlwerke Südwestfalen, A.G., Werk Geisweid, Geisweid, Kries Siegen, Germany. (*Ingots, bars, billets, thin plates, sheets and coils*)

Copenhagen

Burmeister & Wain's Maskin-og Skibsbyggeri, Aktieselskabet, Copenhagen, Denmark. (*Ingots, forgings and castings*)

Danske, (Det), Staalvalsevaerk A/S., Frederiksvaerk, Denmark. (*Plates, sections and bars*)

Helsingors Skibsvaerft-og Maskinbyggeri A/S., Aktieselskabet, Elsinore, Denmark. (*Forgings and castings*)

Dortmund

Edelstahlwerk Witten A.G., Witten-Ruhr, Germany. (*Ingots, billets, bars, forgings and narrow flats*)

Eisenwerk Bohmer, Witten, Ruhr, Dortmund, Germany. (*Castings*)

Eisenwerk Geweke, R. & C. R. Lange K.G., Hagen-Haspe, Germany. (*Electric steel castings*)

Dortmund—*continued*

Eisenwerk Rödinghausen K. G., Lendringsen Krs. Iserlohn, Germany. (*Castings*)

Gottwald, Leo Werk Hattingen, Ruhr, Germany. (*Small forgings*)

Gussstahlwerk Carl Bönnhoff, Wetter/Ruhr, Germany. (*Ingots and castings*)

Gussstahlwerk Wittman A.G., Hagen-Haspe, Germany. (*Castings*)

Hoesch Hüttenwerke, A.G., Dortmund, Germany.

Werk Phoenix Hörde, Dortmund-Hörde. (*Ingots, plates and castings*)

Werk Union, Dortmund. (*Bars and sections*)

Werk Westfalenhütte, Dortmund. (*Ingots, billets, plates, bars and sections*)

Klöckner-Werke A.G., Hütte-Haspe, Hagen Haspe, Germany. (*Rolling mills for bars*)

Knorr-Bremse G.m.b.H., Volmarstein-Schmandbruch, Germany. (*Castings*)

Kruiner Gussstahlwerk, Gevelsberg, Germany. (*Castings*)

Paderwerk Gebr. Benteler, Schlossneuhaus, Germany. (*Seamless tubes*)

Rheinstahl Hüttenwerke A.G., Henrichshütte, Hattingen, Ruhr, Germany. (*Ingots, plates, forgings and castings*)

Schutte, Meyer & Co., G.m.b.H., Letmathe, Westphalia, Germany. (*Small castings*)

Stahlwerke Südwestfalen A.G., Werksgruppe Hagen, Werk Wehringhausen, Hagen, Germany. (*Ingots, bars and forgings*)

Wittener Hutte Aktiengesellschaft, Witten, Ruhr, Germany. (*Castings*)

Dunkerque

Compagnie des Ateliers et Forges de la Loire, Usine des Dunes, Malo les Bains (Nord), France. (*Ingots, billets, blooms, bars and forgings*)

Generale d'Hydraulique et de Mecanique, Usine Metallurgiques de Marquise Rinxent, Pas de Calais. (*Castings*)

Paris et d'Outreau, Acieries de, Société Anonyme, Usines d'Outreau Pas de Calais. (*Castings*)

Union Siderurgique du Nord et de l'Est de la France, "USINOR", Usine de Dunkerque, Dunkerque (Nord), France. (*Ingots and plates*)

Durban

Mangolds Engineering, Port Elizabeth, South Africa. (*Small castings*)

Dusseldorf

August Thyssen-Hütte A.G., Duisburg-Hamborn, Germany.

Area Hamborn. Steelworks Beeckerwerth, Bruckhausen and Ruhrort. (*Ingots, billets, slabs, plates and sections*)

Area Mülheim. Steelworks Mülheim. (*Ingots, slabs and plates*)

Duisburg Huttenheim. (*Plates*)

Dusseldorf—*continued*

Bergische Stahlindustrie K.G., Remscheid, Germany. (*Castings*)

Deutsche Edelstahlwerke A.G., Krefeld, Germany. (*Ingots, forgings and rolled materials*)

Fried. Krupp Hüttenwerke A.G., Bochum, Germany.
Works: Bochum. (*Ingots, plates, forgings, castings and bars*)
Works: Rheinhausen. (*Ingots, bars and sections*)

Grossmann, C., Eisen-und Stahlwerk A.G., Solingen-Wald, Germany. (*Castings*)

Gutehoffnungshütte Sterkrade A.G., Werk Sterkrade, Oberhausen-Sterkrade, Germany. (*Forgings*)

Hüttenwerk Oberhausen, A.G., Oberhausen, Germany. (*Ingots, plates, sections and bars*)

Mannesmann A.G. Hüttenwerke, Duisburg-Huckingen, Germany. (*Ingots, slabs and bars*)

Mannesmannrohren-Werke G.m.b.H., Dusseldorf. Germany. (*Seamless and welded tubes*)

Meyer, F. Stahl, -Draht & Röhrenwerke, Dinslaken, Germany. (*Ingots, billets for tubes and bars*)

Niederrheinische Hutte A.G., Duisburg, Germany. (*Rolling mill for narrow flats and sections*)

Rheinstahl Giesserei A.G., Gussstahlwerke Gelsenkirchen, Germany. (*Castings*)

Rheinstahl Giesserei A.G., Gussstahlwerke Oberkassel, Dusseldorf-Oberkassel, Germany. (*Ingots and castings*)

Rheinstahl Hüttenwerke A.G.,
Werk Friedrich Wilhelms-Hütte, Mülheim und Meiderich, Germany. (*Castings*)

Stahl- u. Röhrenwerke Reisholz G.m.b.H.,
Works at Reisholz. (*Ingots and seamless tubes*)
Works at Oberbilk. (*Forgings*)

Stahlwerke Bochum A.G., Bochum, Germany. (*Castings, rolled materials and plates*)

El Ferrol

Astilleros y Talleres del Noroeste S.A., El Ferrol del Caudillo, Spain. (*Small forgings and small castings*)

Empresa Nacional Bazan, El Ferrol del Caudillo, Spain. (*Castings*)

Emden

Sande, Giesserei, Sande-Oldenburg, Germany. (*Castings*)

Fremantle

Australian Iron & Steel Pty. Ltd., Steelworks, Kwinana, W. Australia. (*Small bars and sections*)

Hadfields (W.A.) 1934 Ltd., Perth, W. Australia. (*Castings*)

Gdansk

Zaklady Mechaniczne Im. Gen. K., Swierczewskiego, Elblag, Poland. (*Castings*)

Zaklady Metalurgiczne Poznan, "Pomet", Poznan ul Krancowa 15, Poland. (*Castings*)

Genoa

A.S.S.A. Acciaierie di Susa Società Anonima, Turin, Italy. *Head Office:* Turin. *Works:* Susa. (*Castings*)

Ansaldo Meccanico Nucleare S.p.A., Stabilimento Fonderia di Ghisa e Metalli, Genova-Pegli, Italy. (*Forgings*)

Cantieri Navali del Tirreno e Riuniti, S.p.A., Riva Trigoso, Genoa, Italy. (*Small forgings*)

FIAT, Società per Azioni, Sezione Ferriere Piemontesi, Turin, Italy. (*Ingots, plates, sections; also seamless and welded tubes*)

Fit Ferrotubi-Fabbrica Italiana Tubi Ferrotubi, Italy. (*Ingots, billets and weldless rolled and drawn tubes*)

Fonderia Acciaieria Giovanni Mandelli, Turin, Italy. (*Castings*)

"ITALSIDER" S.p.A. *Head Office:* Via Corsica 4, Genoa, Italy.
S.I.A.C., Genoa. (*Ingots, forgings, plates and castings*)
Oscar Sinigaglia Works, Genoa-Cornigliano. (*Ingots, slabs and plates*)

Nazionale "Cogne", S.p.A. *Head Office:* Turin, Italy. *Works:* Aosta. (*Ingots, forgings, plates, sections and bars*)

Gijon

Duro-Felguera, Sociedad Metalúrgica, La Felguera, Asturias, Spain. (*Castings*)

Empresa Nacional Siderurgica, S.A. (ENSIDESA), Avilés, Spain. (*Ingots, slabs and billets for re-rolling, plates and sections*)

Talleres de Moreda S.A., Gijon. (*Forgings*)

Trubia, Fábrica Nacional de, Trubia Asturias, Spain. (*Castings and forgings*)

Union de Siderurgicas, Asturianas, S.A. (UNINSA)
Fabrica de Mieres, Asturias, Spain. (*Sections, bars and plates up to* 15 *mm in thickness*)
Fabrica de Gijon, Gijon, Spain. (*Rivet bars and castings*)
Factoria de La Felguera, La Felguera, Asturias, Spain. (*Ingots, billets, plates and sections*)

Gothenburg

Björneborgs Jernverks Aktiebolag, Björneborg, Sweden. (*Ingots and forgings*)

Bofors Aktiebolaget, Bofors, Sweden. (*Ingots, forgings, castings and rolled bars*)

Klafreströms Bruk, A/B, Klavreström, Sweden. (*Small castings*)

Motala Verkstad, A/B, Motala Verkstad, Sweden. (*Ingots and castings*)

Stridsberg & Biorck, A.B., Trollhattan, Sweden. (*Castings*)

Svenska Kullagerfabriken A/B, Hellefors Jernverk, Hällefors, Sweden. (*Ingots and bars*)

Uddeholms Aktiebolag, Uddeholm, Sweden.
Works at Degerfors. (*Ingots, plates, sections and bars*)
Works at Hagfors. (*Castings, ingots, forgings, bars and sections*)
Works at Nykroppa. (*Ingots*)
Works at Storfors. (*Seamless tubes*)

Halifax, N.S.

Hawker Siddeley Canada Ltd., Trenton Works, Trenton, N.S. (*Forgings*)

Maritime Steel and Foundries, Ltd., New Glasgow, N.S. (*Small castings*)

Sydney Steel Corporation, Sydney, N.S., (*Ingots, billets and sections*)

Hamburg

Ellerbrock, Hans, Stahlgiesserei und Maschinenfabrik, Hamburg, Germany. (*Castings*)

Hannover

Eisen-und Stahlwerk Pleissner G.m.b.H., Herzberg/Harz, Germany. (*Castings*)

Friedrich-Carl-Hütte G.m.b.H., Delligsen über Alfeld/Leine, Germany. (*Castings*)

Ilseder Hütte/Peine, Hüttenbetriebe, Peine, Germany. (*Ingots, billets, sections and bars*)

Klöckner - Werke A.G. Georgsmarienwerke, Osnabrück, Germany. (*Ingots, bars, forgings and castings*)

Salzgitter Hüttenwerk A.G., Salzgitter-Drütte, Germany. (*Ingots, plates, bars and sections*)

Sollinger Hütte G.m.b.H., Uslar/Solling, Germany. (*Castings*)

Tweer, Reinhard, G.m.b.H., Sennestadt/Westf., Germany, *Works:* Sennestadt. (*Castings*)

Haren-Groningen

Stork-Volma N.V. Gorredijk, Holland. (*Small castings*)

Helsingborg

Hoganas A/B, Hoganas, Sweden. (*Castings*)

Helsinki/Helsingfors

Ahlstrom, A., Oy, Osakeyhtio Karhulan Tehtaat, Karhula Bruk, Karhula, Finland. (*Castings*)

Stenburg, John, OY-AB, Helsingfors, Finland. (*Small castings*)

Vuoksenniska Oy, Aktiebolag, Imatra Steel Works, Imatra, Finland. (*Ingots, slabs, blooms and billets, bars, sections and castings*)

Hiroshima

Kotobuki Kogyo Co., Ltd., Hiro Works, Kure, Japan. (*Castings*)

Hong Kong

Cheoy Lee Shipyard, Lantau Island, Hong Kong. (*Castings*)

Shun Fung Ironworks Ltd., Kowloon, Hong Kong. (*Castings*)

Istanbul

Makine ve Kimya Endustri, Celik Fabrikasi, Kirikkale, Turkey. (*Ingots, forgings, rolled sections and bars*)

Turkiye Demir ve Celik Isletmeleri, Karabuk, Turkey. (*Ingots, thin plates, rolled sections and bars*)

Jamshedpur

Heavy Engineering Corp. Ltd., Foundry Forge Plant, P. O. Dhurwa, Ranchi, India. (*Castings*)

Katowice

Huta 1-Maja, Gliwice, Poland. (*Ingots and forgings*)

Huta Baildon, Katowice, Poland. (*Ingots, forgings and bars*)

Huta Batory, Chorzow-Batory, Poland. (*Forgings, plates and tubes*)

Huta Bierut, Czestochowa, Poland. (*Seamless tubes*)

Huta Bobreck, Bytom, Poland. (*Ingots, slabs and blooms*)

Huta im M. Buczka, Sosnowiec, Poland. (*Seamless tubes*)

Huta Dzierzynski, Dabrowa Gornicza, Poland. (*Billets, sections and bars*)

Huta Florian, Swietochlowice, Poland. (*Angles and bars*)

Huta Jednosc, Siemianowice Slaskie, Poland. (*Ingots and seamless tubes*)

Huta Kosciuszko, Chorzow, Poland. (*Billets, blooms, sections and rivet bars*)

Huta Labedy, Labedy, Poland. (*Flats and sections*)

Huta im. Lenina, Krakow, Poland. (*Ingots, slabs, plates up to 12 mm*)

Huta Malapanew, Ozimek k/Opola, Poland. (*Castings*)

Huta Nowotko, Ostrowiec Swietokrzyski, Poland. (*Sections*)

Huta Pokoj, Ruda Slaska, Poland. (*Plates, sections and small forgings*)

Huta Stalowa Wola, Stalowa Wola, Poland. (*Castings, forgings, plates and sections*)

Huta Zawiercie, Zawiercie, Poland. (*Flats and bars*)

Zaklady Urzadzen Chemicznych i Armatury Przemyslowej Kielce, Poland. (*Castings*)

Zaklady Urzadzen Technicznych "Zgoda", Swietochlowice, Poland. (*Forgings*)

Kiel

Nordische Stahlwerke, Bach & Co., Neumünster, Germany. (*Castings*)

Kobe

Aichi Steel Works Ltd.

- Chita Plant, Aichi Prefecture, Japan. (*Ingots and bars*)
- Kariya Plant, Aichi Prefecture, Japan. (*Ingots and bars*)

Asano Tekkosho Co., Ltd., Saijo-Shi, Shikoku, Japan. (*Small forgings*)

Chubu Steel Plate Co., Ltd., Nakagawa Works, Nagoya, Japan. (*Ingots and plates*)

Daido Steel Co., Ltd.

- Chita Plant, Nagoya, Aichi Prefecture, Japan. (*Ingots, billets and bars*)
- Hoshizaki Plant, Nagoya, Japan. (*Ingots and bars*)
- Tsukiji Plant, Nagoya, Japan. (*Ingots, forgings and castings*)

Kobe—*continued*

Daitetsu Steel Industrial Co., Ltd., Osaka, Japan. *(Ingots and sections)*

Endo Iron Works Co., Ltd., Osaka, Japan. *(Forgings)*

Go Iron Works, Ltd., Tarui Works, Tarui, Japan. *(Small castings)*

Hitachi Metals, Ltd., Yasugi Works, Yasugi, Japan. *(Ingots, bars and forgings)*

Hitachi Shipbuilding & Engineering Co., Ltd.
- Chikko Shipyard, Osaka, Japan. *(Ingots castings, and forgings)*
- Innoshima Shipyard, Innoshima, Japan. *(Forgings and small castings)*

Howa Machinery, Ltd., Inazawa Plant, Aichi Prefecture, Japan. *(Castings)*

Ishikawajima-Harima Heavy Industries Co., Ltd., Aioi Works, Aioi, Japan. *(Castings and forgings)*

Izuo Chukosho Co., Ltd., Osaka, Japan. *(Castings)*

Japan Drop Forge Co., Ltd., Amagasaki, Japan. *(Small forgings)*

Japan Iron-Sand Steel Co. Ltd., Shikama Works, Himeji, Japan. *(Ingots, bars and sections)*

Kansai Steel Corp., Sakai, Japan. *(Ingots, bars and flat bars)*

Kansai Tekko Co., Ltd., Amagasaki, Japan. *(Small forgings)*

Kawasaki Heavy Industries Ltd.
- Hyogo Cast Steel Works, Kobe, Japan. *(Castings)*
- Kobe Works, Kobe, Japan. *(Castings)*

Kawasaki Steel Corporation.
- Chita Works, Handa City, Japan. *(Ingots and castings)*
- Fukiai Works, Kobe, Japan. *(Blooms and sections)*
- Hyogo Works, Kobe, Japan. *(Castings and forgings)*
- Mizushima Works, Mizushima, Japan. *(Ingots, forgings, castings, bars and plates)*
- Nishinomiya Works, Nishinomiya, Japan. *(Ingots and thin plates)*

Kinka Kikai Co., Ltd., Gifu, Japan. *(Castings)*

K.K. Teikoku Kokan Seizosho, Osaka, Japan. *(Seamless tubes)*

Kobe Steel Ltd.
- *Works:* Amagasaki, Japan. *(Ingots, sections and bars)*
- *Works:* Kakogawa Plant, Kakogawa City, Hyogo Prefecture, Japan. *(Rolling mills for plates)*
- *Works:* Kobe, Japan. *(Ingots, blooms, billets, bars castings and seamless tubes)*
- *Works:* Takasago Plant, Takasago, Japan. *(Ingots, forgings and castings)*

Kokko Steel Works, Ltd., Osaka, Japan. *(Ingots, bars and castings)*

Kokoku Steel Casting Co., Ltd., Osaka, Japan. *(Castings)*

Komatsu Ltd.
- Awazu Plant, Komatsu, Japan. *(Castings)*
- Osaka Plant, Hirakata, Osaka Prefecture, Japan. *(Castings)*

Kobe—*continued*

Kubota Ltd., Hirakata Plant, Hirakata, Osaka, Japan. *(Castings)*

Kureha Seiko Co., Ltd., No. 1, 5-Chome Takeshima-Cho, Nishiyodogawa-Ku, Osaka, Japan. *(Castings)*

Kurimoto Iron Works Ltd., Kagaya Factory, Osaka, Japan. *(Castings)*

Maekawa Electric Steel Castings Co., Osaka, Japan. *(Castings)*

Maizuru Jukogyo Ltd., Maizuru, Japan. *(Small castings)*

Mitsubishi Heavy Industries Ltd.
- Kobe Shipyard & Engine Works, Kobe, Japan. *(Ingots, small forgings and castings)*
- Mihara Machinery Works, Mihara, Japan. *(Castings and forgings)*
- Takasago Machinery Works, Takasago, Japan. *(Forgings)*

Mitsui Shipbuilding & Engineering Co., Ltd., Japan,
- Fujinagata Works, Osaka, Japan. *(Forgings)*
- Tamano Works, Tamano, Japan. *(Ingots, forgings and castings)*

Mitsumoto Valve Manufacturing Co., Ltd., Domyoji, Osaka, Japan. *(Small forgings and small castings)*

Miyazaki Iron Works, Co., Ltd., Osaka, Japan. *(Small forgings)*

Nakayama Steel Works, Ltd., Osaka, Japan. *(Ingots and plates)*

Nippon Kokan Kabushiki Kaisha, Fukuyama Iron Works, Fukuyama, Japan. *(Ingots, blooms and plates)*

Nippon Sharyo Seizo Kaisha Ltd., Nagoya, Japan. *(Castings)*

Nippon Steel Corporation.
- Hirohata Works, Himeji City, Japan. *(Ingots, billets, plates and sections)*
- Nagoya Works, Nagoya, Japan. *(Ingots and plates)*
- Sakai Works, Sakai, Osaka, Japan. *(Ingots, sections and thin plates)*

Nippon Steel Foundry Co., Ltd., Osaka, Japan. *(Castings)*

Nisshin Seiko Co., Ltd., Shikama Plant, Himeji, Japan. *(Rolled sections and bars)*

Ohtani Heavy Industrial Co., Ltd.
- Amagasaki Plant, Amagasaki, Japan. *(Plates up to 12,5 mm in thickness)*

Okamoto Iron Works Co., Kobe, Japan. *(Forgings)*

Onomichi Anchor Manufacturing Co., Ltd., Onomichi, Japan. *(Castings)*

Osaka Chain & Machinery Manufacturing Co., Ltd., Kaizuka Works, Osaka, Japan. *(Small castings)*

Osaka Steel Casting Co., Ltd., Osaka, Japan. *(Small castings.)*

Rikimi Cast Steel Co. Ltd., Osaka, Japan. *(Small castings)*

Sanyo Special Steel Co. Ltd., Himeji, Japan. *(Ingots, forgings and rolled bars)*

Kobe—*continued*

Seo Koatsu Kogyo Co., Ltd., Osaka, Japan. (*Small forgings*)

Sumitomo Electric Industries, Ltd., Itami Works, Itami, Hyogo Prefecture, Japan. (*Ingots and small bars*)

Sumitomo Metal Industries, Ltd.
- Osaka Steel Works, Osaka, Japan. (*Castings, forgings and bars*)
- Steel Tube Works, Amagasaki, Japan. (*Ingots, forgings, small bars, sections and weldless tubes*)
- Wakayama Steel Works, Wakayama, Japan. (*Ingots, plates, seamless tubes and electric resistance welded tubes*)

Sumitomo Shipbuilding & Machinery Co., Ltd.
- Niihama Works, Niihama, Japan. (*Castings*)
- Tamashima Works, Tamashima, Japan. (*Castings*)

Takada Steel Works, Ltd., Takada City, Nara Prefecture, Japan. (*Castings*)

Teikoku Chukosho Co., Ltd., Osaka, Japan. (*Castings*)

Tokai Special Steel Co., Ltd., Nagoya, Japan. (*Ingots*)

Topy Industries Ltd., Toyohashi Works, Toyohashi, Japan. (*Ingots, sections and flat bars*)

Toyo Kikai-Kinzoku Co., Ltd., Tsuchiyama Plant, Akashi, Japan. (*Small castings and small forgings*)

Wasino Machine Co., Ltd.
- Imamura Plant, Aichi Prefecture, Japan. (*Castings*)
- Komaki Plant, Aichi Prefecture, Japan. (*Small castings*)

Yamato Kogyo Co., Ltd., Himeji, Japan. (*Castings*)

Yamato Steel Works, Ltd., Osaka, Japan. (*Ingots, sections and plates*)

Yonago Steel Works, Ltd., Yonago, Japan. (*Castings*)

La Spezia

Faggian, Acciaierie Elettriche Pio, Soc. per Azioni, La Spezia, Italy. (*Small castings*)

Leghorn

"ITALSIDER" Alti Forni e Acciaierie Ruinite Ilva e Cornigliano S.p.A., Stabilimento di Portovecchio di Piombino, Italy. (*Ingots, blooms, sections and bars*)

Lisbon

"COMETNA" Companhia Metalurgica Nacional, S.A.R.L., Amadora, Portugal. (*Castings*)

Fundicoes do Rossio de Abrantes S.A.R.L., Rossio de Abrantes, Portugal. (*Castings*)

Metalurgica Duarte Ferreira S.a.r.l., Tramagal, Portugal. (*Castings*)

Siderurgia Nacional, S.a.r.l., Seixal, Portugal. (*Sections and bars*)

União Fabril, Companhia, Barreiro, Portugal. (*Castings*)

Los Angeles

Bethlehem Steel Co., Los Angeles 54, Cal., U.S.A. (*Round bars*)

Kaiser Steel Corporation, Fontana, Cal., U.S.A. (*Ingots and plates*)

Los Angeles Steel Casting Co., Los Angeles, Cal., U.S.A. (*Castings*)

United States Steel Corporation.
- Torrance Works, Torrance, Calif., U.S.A. (*Round bars and sections*)
- Geneva Works, Provo, Utah, U.S.A. (*Plates*)

Lyons

Temple, Aciéries du, Saint-Michel de Maurienne, (Savoie) France. (*Rolled and forged bars and billets*)

Malmö

Anderson, Aktiebolaget Abjörn, Svedala, near Malmö, Sweden. (*Castings*)

Kockums Jernverk, Kallinge, Sweden. (*Ingots and castings*)

Mannheim

Dingler, Karcher & Cie., G.m.b.H., Saarländisches Stahlwerk, Worms/Rhein. (*Castings*)

Stahlwerk Mannheim A.G., Mannheim-Rheinau (*Castings*)

Marseilles

Ateliers du Creusot, Société des Forges et Usines Schneider, Usine de Pamiers, Pamiers, France. (*Castings and forgings*)

Feurs, Fonderies & Acieries Electriques de, Feurs (Loire), France. (*Small castings*)

Marrel Frères, Société Anonyme des Etablissements, Usine des Etaings, near Rive-de-Ciers (Loire), France. (*Ingots, forgings, plates and bars*)

Pont A Mousson, Societe des Fonderies de, Usine de Fumel, France. (*Castings, centrifugal cast pipes*)

Provence, Fonderies et Aciéries de, Marseilles, France. (*Castings*)

Saut-du-Tarn, Société Anonyme des Forges et Aciéries du, Saint-Juéry (Tarn), France. (*Castings*)

Tamaris, Société des Ateliers et Fonderies des, Tamaris (Gard), France. (*Castings*)

Ugine Kuhlmann, Savoie, France. (*Ingots, billets, bars, sections, castings and forgings*)

Melbourne

Davies & Baird Pty., Ltd., Newlands Road, Coburg, Melbourne, Australia. (*Castings*)

Steel Company of Australia, Pty., Ltd., Coburg, Melbourne. (*Castings*)

Vickers, Ruwolt, Pty., Ltd., Richmond, Melbourne. (*Steel castings and ingots*)

Metz (*Saarbrücken District*)

de Wendel et Cie., S/A, Hayange, Moselle, France.
Usine de Fenderie. (*Plates*)
Usine de St. Jaques. (*Sections*)

Pompey, Société des Aciéries de, Usine de Pompey, Meurthe et Moselle, France. (*Ingots, blooms, billets, plates, angles and round bars*)

S.A.F.E., Société des Aciers Fins de l'Est, Hagondange, Moselle, France. (*Ingots, blooms, billets, bars, plates and sheets*)

Société Lorraine de Laminage Continu, Sollac, B.P.11, Florange, Moselle, France. (*Ingots, slabs and plates*)

Société Mosellane de Siderurgie, Hagondange (Moselle), France. (*Blooms, billets, bars and sections*)

Union Sidérurgique Lorraine, SIDELOR, Usine d'Homécourt, Meurthe et Moselle, France. (*Ingots, blooms, billets, narrow plates and universal flats*)
Usine de Rombas, Moselle, France. (*Ingots, blooms, billets, bars and sections*)

Union Siderurgique du Nord et de l'Est de la France, "USINOR".
Groupe C
Usine de Longwy (Meurthe et Moselle), France.
Section Mont Saint Martin. (*Sections and plates*)
Section Senelle. (*Ingots, blooms, bars and sections*)
Usine de Thionville, Thionville (Moselle), France. (*Forgings and castings*)

Wendel-Sidelor, Usine de Micheville, Villerupt, Meurthe et Moselle, France. (*Ingots, blooms, billets, bars and sections*)

Mexico City

Altos Hornos de Mexico S.A., (A.H.M.S.A.), Monclova, Coah., Mexico. (*Plates*)

Milan

Amsco Italiana S.p.A., Milan. (*Small castings*)

Breda Fucine, S.p.A., Sesto San Giovanni, Milan. (*Castings and forgings*)

Breda Siderurgica, S.p.A., Sesto San Giovanni, Milan. (*Ingots and sections*)

Brescia, Acciaieria e Turbificio di, S.p.A., Brescia. (*Ingots, sections, bars and castings*)

Caleotto, Acciaieria e Ferriera del, S.p.A., Lecco. (*Ingots, castings, bars, small sections and small forgings*)

Carlo Tassara, Stabilimenti Electtrosiderurgici S.p.A., Breno, Brescia, Italy. (*Ingots and small forgings*)

Ceretti, Pietro Maria, S.p.A., Ferriera dell' Ossola-Villadossola. (*Castings*)

Dalmine, S.p.A. *Head Office:* Milan.
Dalmine Costa Volpino, Bergamo. (*Seamless tubes*)
Dalmine Works, Bergamo. (*Ingots and seamless tubes*)

Falck, Acciaierie e Ferriere Lombarde. *Head Office & Works:* Milan. (*Weldless rolled or drawn tubes*)
Concordia Works, Sesto San Giovanni, Milan. (*Ingots and plates*)
Unione Works, Sesto San Giovanni, Milan. (*Ingots, sections, bars, forgings and castings*)

Milan—*continued*

FOMAS—Forgiatura Moderna Acciai Speciali S.p.A., Osnago, (Como), Italy. (*Forgings*)

"ITALSIDER" Alti Forni e Acciaierie Riunite Ilva e Cornigliano S.p.A., Stabilimento di Lovere. (*Sections, bars, castings and forgings*)

Luigi Giudici, Società per Azioni, Rescaldina, Milan. (*Small castings*)

Metallurgica Marcora, S.n.C., Busto Arsizio (Varese). (*Weldless rolled and drawn tubes*)

S.I.S.M.A.—Società Industrie Siderurgiche Meccaniche & Affini, Villadossola (Novara). (*Rolled bars and rivets*)

Stramezzi, P., & C., Acciaieria e Ferriera di Crema, Crema. (*Ingots, bars, small sections and rivets*)

Tosi, Franco, S.p.A., Legnano. (*Forgings and castings*)

Villa, Giovanni, S.p.A., Officine Meccaniche-Fucinati-Stampati, Milan. (*Forgings*)

Mobile, Ala.

Kilby Steel Co., Furnace Division, Anniston, Ala., U.S.A. (*Ingots*)

Republic Steel Corporation, Alabama City, Ala., U.S.A.

Tennessee Coal & Iron Division, United States Steel Corporation, Birmingham, Ala., U.S.A. *Works:* Ensley, Ala.; *Rolling mills and forgings:* Bessemer and Fairfield, Ala.

Montreal

Canadian Steel Foundries Division Hawker Siddeley Canada, Ltd., Longue Pointe, Montreal, P.Q., Canada. (*Castings*)

Canadian Unitcast-Steel, Ltd., Sherbrooke, P.Q., Canada. (*Castings*)

Crucible Steel Company of Canada, Ltd., Sorel, P.Q., Canada. (*Ingots and forgings*)

Dominion Steel & Coal Corporation Ltd., Montreal Works, 5870, St. Patrick Street, Montreal, P.Q., Canada. (*Angles, bars and rivets*)

Lynn Macleod Metallurgy, Ltd., Thetford Mines, P.Q., Canada. (*Castings*)

Manitoba Rolling Mills Division of Dominion Bridge Co., Ltd., Selkirk, Manitoba, Canada. (*Billets, bars and sections*)

Sorel Steel Foundries, Ltd., Sorel, P.Q., Canada. (*Castings*)

Steel Company of Canada, Hamilton, Ontario, Canada. *Works:* Montreal. (*Bars and angles, plates and billets*)

Nagasaki

Mitsubishi Heavy Industries Ltd., Nagasaki Works, Nagasaki, Japan. (*Castings*)

Mitsubishi Steel Manufacturing Co., Ltd., Nagasaki Works, Nagasaki, Japan. (*Ingots, blooms, plates, forgings and castings*)

Nagasaki—*continued*

Osaka Steel, Tube Co., Ltd., Sasebo Works, Sasebo, Japan. (*Seamless tubes*)

Sasebo Heavy Industries Co., Ltd., Sasebo, Japan. (*Ingots, forgings and castings*)

Nantes

Sambre et Meuse, Société Anonyme des Usines & Aciéries de, Usines de Saint Brieuc (Côtes-du-Nord.) (*Small castings*)

Naples

Fucine Meridionali, S.p.A., Bari, Italy. (*Castings and forgings*)

"ITALSIDER" Alti Forni e Acciaierie Riunite Ilva e Cornigliano S.p.A.
Stabilimento di Taranto. (*Ingots, slabs and plates*)

"ITALSIDER" S.p.A., Centro Siderurgico di Bagnoli, Naples. (*Ingots, sections and bars*)

Meridionali, Acciaierie e Tubificio, S.p.A., Bari, Italy. (*Castings and weldless rolled or drawn tubes*)

Safog, S.A.—Stabilimento di Napoli, Naples, Italy. (*Castings*)

"Terni" Società per l'Industria e l'Elettricha.
Works: Terni. (*Ingots, forgings, castings and plates*)

Newcastle, N.S.W.

Broken Hill Proprietary Co., Ltd., Iron and Steel Works, Newcastle, N.S.W. (*Ingots, billets, plates, sections, strip and castings*)

Commonwealth Steel Co., Ltd., Waratah, Newcastle, N.S.W. (*Castings, forgings, ingots and bars*)

Newport News, Va.

Newport News Shipbuilding & Dry Dock Co., Newport News, Va., U.S.A. (*Castings and forgings*)

Odense

Varde Staalvaerk, Varde, Denmark. (*Ingots and castings*)

Oslo

Christiania Spigerverk, Oslo. (*Ingots and bars, also rivet bars*)

Drammens Jernstoberi & Mek-Verksted, A/S, Drammen. (*Small castings*)

Norsk Jernverk, A/S, Mo-i-Rana. (*Electric steel ingots, billets, sections and bars*)

Raufoss Ammunisjonsfabrikker, Raufoss. (*Castings*)

Strömmen Staal A/S,
Works: Raufoss. (*Castings*)
Strömmen. (*Castings*)

Paris

Acieries & Fonderies de l'est, France.
Usine de Colombier-Fontaine. (*Small Castings*)
Usine de Sainte-Suzanne. (*Small electric castings*)

Aciéries du Furan, St. Etienne (Loire), France. (*Electric steel castings*)

Aubert et Duval, Anciens Ets., Aciéries des Ancizes (Puy-de-Dôme). (*Ingots, rolled bars and forgings*)

d'Auxonne, Aciéries & Fonderies, Auxonne (Côte d'Or), France. (*Small castings*)

Compagnie des Ateliers et Forges de la Loire.
Usines de l'Ondaine, Firmigny (Loire), France. (*Ingots, billets, blooms, bars, castings and forgings*)
Usines de St. Chamond (Loire), France. (*Forgings*)
Usines de St. Etienne, St. Etienne (Loire), France. (*Plates*)

Creusot, Société des Forges et Ateliers du (S.F.A.C.), Usines Schneider, Le Creusot, France. (*Ingots, forgings, castings, plates and sections*)

Etablissement des Constructions et Armes Navales de Guerigny, Guerigny, France. (*Ingots, bars, forgings and castings*)

Ferry-Captain, S.A.R.L., Usines du Bussy-Joinville, France. (*Electric steel castings*)

Gennevilliers, Aciéries de, Gennevilliers (Seine), France. (*Castings*)

Geugnon, Forges de, Geugnon (S. & L.), France. (*Rolling mill for plates*)

d'Imphy, Société Metallurgique, Aciéries d'Imphy (Nièvre), France. (*Ingots, forgings, bars and sections*)

Paris-Seine, Fonderies et Aciéries, Usine de la Folie, Avenue de Bobigny, Noisy-le-Sec. (Seine), France. (*Castings*)

Philadelphia, Pa.

Atlantic Steel Castings Co., The, Chester, Pa., U.S.A. (*Castings*)

Bethlehem Steel Corporation., Bethlehem, Pa., U.S.A. (*Ingots, forgings, bars and sections*)
Lebanon, Pa., U.S.A. (*Rolling mills for bars and rivets*)
Steelton, Pa., U.S.A. (*Castings*)

Birdsboro Corporation, Birdsboro, Pa., U.S.A. (*Castings*)

Donegal Steel Foundry Company, 601, East Market Street, Marietta, Pa., U.S.A. (*Castings*)

Empire Steel Castings Inc., Reading Pa., U.S.A. (*Castings*)

Lebanon Steel Foundry, Lebanon, Pa., U.S.A. (*Small castings*)

Lukens Steel Company, Coatesville, Pa., U.S.A. (*Plates*)

Midvale-Heppenstall Company, Nicetown, Philadelphia, Pa., U.S.A. (*Forgings*)

Penn Steel Castings Co., Chester, Pa., U.S.A. (*Castings*)

Pennsylvania Forge, Division of Chemetron Corporation, Tacony, Philadelphia 35, Pa., U.S.A. (*Forgings*)

Pennsylvania Steel Foundry and Machine Company, Hamburg, Pa., U.S.A. (*Castings*)

Philadelphia, Pa.—*continued*

Phoenix Steel Corporation.
Works: Claymont, Delaware, U.S.A. (*Plates*)
Works: Structural Division, Phoenixville, Pa., U.S.A. (*Sections, bars and rotary forged seamless tubes*)

Quaker Alloy Casting Co., Myerstown, Pa., U.S.A. (*Small castings*)

Standard Steel Division of Baldwin-Lima-Hamilton Corp., Burnham Pa., U.S.A. (*Forgings*)

United States Steel Corporation, Fairless Works, Fairless Hills, Pa., U.S.A. (*Thin plates, bars and sections*)

Wood, Alan, Steel Company, Conshohocken, Pa., U.S.A. (*Blooms, billets and plates*)

Piraeus

Nicolacopoulos G., & Co., Athens, Greece, Steelworks at Eleusis. (*Castings*)

Viomichania Chalyvon Ltd., Athens Greece. (*Castings*)

Port Kembla

Australian Iron & Steel Pty., Ltd., Port Kembla, N.S.W. (*Plates, bars, sections and forgings*)

Rijeka

Tvornica Dizalica I Ljevaonica "Vulkan" Rijeka 11, Yugoslavia. (*Castings*)

Zelezarna Ravne, Ravne na Koroskem, Yugoslavia. (*Castings, forgings, billets and bars*)

Zeljezara Sisak, Sisak Predgradje, Yugoslavia. (*Seamless tubes*)

Rio de Janeiro

Brasileira de Usinas Metalurgicas, Companhia, Usina de Neves Sao Goncalo, Estado do Rio de Janeiro, Brazil. (*Ingots, sections and bars*)

Companhia Ferro e Aco de Vitoria, Vitoria, State of Espirito Santo, Brazil. (*Rolling mill for bars and sections*)

Companhia Siderurgica Nacional, Usina Presidente Vargas, Volta Redonda, Estado do Rio de Janeiro, Brazil. (*Plates and sections*)

Usinas Siderurgicas de Minas Gerais S.A., Belo Horizonte, Estado de Minas Gerais, Brazil.
Works: Ipatinga, Estado de Minas Gerais. (*Ingots, slabs and plates*)

Rotterdam

Bakker N.V., Machinefabriek-Staalgieterij, Ridderkerk, Holland. (*Ingots and castings*)

Rotterdamsche Droogdok Maatschappij, Rotterdam, Holland. (*Ingots, forgings and small castings*)

Rouen

Société des Aciéries de Pompey, Usines du Manoir à Pitres (Eure), France. (*Castings*)

Société Métallurgique de Normandie, Mondeville, France. (*Ingots, blooms, billets and bars*)

Saarbrücken-Saar

"ARBED," Aciéries Réunies de Burbach - Eich - Dudelange.
Division de Belval, Esch-sur-Allzette, Luxembourg. (*Ingots, blooms, billets, bars, angle bars and sections*)
Division de Differdange, Differdange, Luxembourg. (*Sections and bars*)
Division de Dommeldange, Dommeldange, Luxembourg. (*Ingots, forgings and castings*)
Division d'Esch, Esch-sur-Allzette, Luxembourg. (*Ingots, bars and sections*)
Division de Burbach, Sarrebruck.
Burbach Works. (*Ingots, billets and sections*)
Hostenbach Works. (*Plates*)

A.G. der Dillinger Huttenwerke, Dillingen/Saar. (*Ingots and plates*)

Dingler, Karcher & Cie., G.m.b.H., Saarbrücken, Saar. (*Castings*)

Minière et Métallurgique de Rodange, Luxembourg. (*Sections*)

Neunkircher Eisenwerk A.G. Neunkirchen/Saar.
Neunkirchen Works. (*Ingots, bars and sections*)
Homburg Works. (*Ingots and seamless tubes*)

Pohlig-Heckel Bleichert, Vereinigte Maschinenfabriken A.G., Abt. Stahlformgiesserei, Werk Heckel, Rohrbach/Saar, Germany. (*Castings*)

Röchling'sche Eisen-und Stahlwerke G.m.b.H., Völklingen (Saar). (*Castings, ingots, billets, bars and forgings*)

Rohrenwerke Bous G.m.b.H., Bous/Saar. (*Seamless tubes*)

Union Siderurgique du Nord et de l'Est de la France, "USINOR".
Groupe C.
Usine de Longwy (Meurthe et Moselle), France.
Section Mont Saint Martin. (*Sections and plates*)
Section Senelle. (*Ingots, blooms, bars and sections*)
Usine de Thionville, Thionville (Moselle), France. (*Forgings and castings*)

Wurth, Société Anonyme des Anciens Etablissements Paul, Luxembourg. (*Castings*)

San Francisco, Cal.

Enterprise Engine & Foundry Co., South City, Cal., U.S.A. (*Castings*)

General Metals Corporation, Oakland, Cal., U.S.A. (*Castings*)

Pacific States Steel Corporation, Union City, Cal., U.S.A. (*Ingots, sections and bars*)

Pacific Steel Castings Co., Berkeley, Cal., U.S.A. (*Castings*)

Santos

Companhia Siderurgica Paulista, Cosipa, Cubatao, Sao Paulo, Brazil. (*Ingots and plates*)

Sao Paulo

Acos Villares S.A., Sao Caetano do Sul, Sao Paulo, Brazil. (*Castings, forgings, billets and bars*)

Seattle, Wash.

Bethlehem Steel Co., Seattle, Wash., U.S.A. (*Sections and bars*)

Jorgensen, Earle M. Co., Forge Division, Seattle, Wash.

Olympic Steel Works, Seattle, Wash., U.S.A. (*Castings*)

Washington Iron Works, Seattle, Wash., U.S.A. (*Castings*)

Shimonoseki

Hitachi Ltd., Kasado Works, Kudamatsu, Japan. (*Castings and forgings*)

Hitachi Metals, Ltd., Tobata Works, Tobata, Japan. (*Castings*)

Japan Steel Works Ltd., Hiroshima Works, Hiroshima, Japan. (*Forgings and castings*)

Kure Shipbuilding & Engineering Co., Ltd., Kure, Japan. (*Small forgings*)

Maekawa Electric Steel Castings Co., Ltd., Tobata Factory, Kitakuyushu, Japan. (*Castings*)

Matsuya Kogyo Co., Ltd., Fukuoka, Japan. (*Small forgings*)

Mitsubishi Heavy Industries, Ltd., Hiroshima Works, Hiroshima, Japan. (*Ingots, castings and small forgings*)
  Shimonoseki Shipyard & Engine Works, Shimonoseki, Japan. (*Small forgings*)

Mitsui Miike Machinery Co., Ltd., Miike Works, Omutashi, Japan. (*Castings*)

Nippon Steel Corporation.
  Engineering, Machinery and Foundry Division, Tobata, Kitakyushu, Japan. (*Castings and forgings*)
  Tobata Area Works, Japan. (*Ingots and plates*)
  Yawata Area Works, Japan. (*Plates, sections, ingots and forgings*)

Nisshin Steel Works, Ltd., Kure Works, Kure, Japan. (*Ingots, blooms, billets and strip*)

Okano Valve Manufacturing Co., Ltd., Moji. *Works:* Yukuhashi, Japan. (*Small castings and small forgings*)

Ozuki Seikosho Ltd., Shimonoseki, Japan. (*Castings*)

Sumitomo Metal Industries, Ltd., Kokura Steel Works, Kitakyushu-City, Japan. (*Ingots, billets, bars and sections*)

Ube Industries, Ltd., Ube Machinery Works, Ube, Japan. (*Ingots, forgings and castings*)

Wakamatsu Sharyo Co. Ltd., Kitakyushu-City, Japan. (*Small castings*)

Singapore

National Iron & Steel Mills Ltd., Jalan Besi Baja, Jurong Industrial Estate, Singapore. (*Small sections and bars*)

Split

Industrija Masina i Livnica, Tuzla, Yugoslavia. (*Castings*)

Rudarsko-Metalurski Kombinat-Zenica, Zeljezara Zenica, Zenica, Yugoslavia. (*Billets, bars, sections and forgings*)

Rudnici i Zelezara Smederevo, Smederevo, Yugoslavia. (*Small castings*)

Rudnici I Zelezarnica, "Skopje", Skopje, Yugoslavia. (*Plates*)

Titovi Zavodi Litostroj, Ljubljana, Yugoslavia. (*Castings*)

Zelezarna Jesenice, Jesenice, Yugoslavia. (*Plates, bars, sections and castings*)

Zeljezara "Boris Kidric", Niksic, Yugoslavia. (*Plates and castings*)

Stockholm

Aktiebolaget Jarnforadling, Halleforsnas, Sweden. (*Small castings*)

Avesta Jernverks Aktiebolag, Avesta, Sweden. (*Plates, sections and castings*)

Boxholms A/B., Boxholm, Sweden. (*Ingots, rolled slabs, blooms, billets, sections and bars*)

Fagersta Bruks Aktiebolag, Fagersta, Sweden (Brukskoncernen).
  Works: Fagersta. (*Blooms, billets, forgings, rolled bars and electric resistance welded tubes*)
  Works: Forsbacka. (*Blooms, billets, forged and rolled bars*)
  Works: Osterbybruk. (*Castings, forgings and rolling mill for bars*)

Hallstahammar Aktiebolag, Hallstahammar, Sweden. (*Bars*)

Hults Bruk A.B., Aby, Sweden. (*Castings*)

Kanthal, A/B, Hallstahammer, Sweden. (*Ingots, billets, bars and castings*)

Kohlswa Jernverks Aktiebolag. (*Ingots, forgings and castings*)

Nordiska Armaturfabrikerna, A/B, Linköping, Sweden. (*Castings*)

Norrbottens Järnverk Aktiebolag, Lulea, Sweden. (*Ingots, slabs, blooms and billets, bars and sections*)

Oxelosunds Jarnverk, Oxelosund, Sweden. (*Ingots, rolled slabs and plates*)

Ramnas Bruks Aktiebolag, Ramnas, Sweden. (*Rolling mills for bars*)

SKF, Stål Hofors Bruk, Hofors, Sweden. (*Billets, bars, forgings and thick walled tubes*)

Sandvikens Jernverks Aktiebolag, Sandviken, Sweden. (*Ingots, forgings, and tubes*)

Smedjebackens Valsverks Aktiebolag, Smedjebacken, Sweden. (*Bars, sections and ingots for re-rolling*)

Stora Kopparbergs Bergslags A/B Specialstålverken, Vikmanshyttan, Sweden. (*Forgings, bars and sections*)

Stockholm—*continued*

Stora Kopparbergs Bergslags Aktiebolag, Falun, Sweden.
Works: Domnarfvet. (*Ingots, sections and plates*)
Works: Söderfors. (*Forgings, bars and sections*)

Surahammars Bruks Aktiebolag, Surahammar, Sweden. (*Plates, forgings and castings*)

Svenska Jarnvagsverkstaderna, A/B, Linköping, Sweden. (*Castings*)

Svenska Kullagerfabriken, Aktiebolaget, Katrineholm, Sweden. (*Castings*)

Stuttgart

Streicher, M., Asperg/Wurtt, near Stuttgart, Germany. (*Castings*)

Sydney, N.S.W.

Bradford, Kendall, Ltd., Alexandria, Sydney, N.S.W. (*Castings*)

Hadfields Steel Works, Ltd., Alexandria, Sydney, N.S.W. (*Castings and forgings*)

Industrial Steels, Ltd., Lidcombe, Sydney, N.S.W. (*Castings*)

Tampico

Fundidora de Fierro y Acero de Monterrey, S.A., Monterrey, N.L., Mexico. (*Plates*)

Toronto, Ontario

Algoma Steel Corporation, Ltd., Sault Ste. Marie, Ontario, Canada. (*Plates, sections and bars*)

Atlas Steels Company, Welland, Ontario, Canada. (*Ingots and bars*)

Black Clawson-Kennedy, Owen Sound, Ontario, Canada. (*Castings*)

Burlington Steel Company, Division of Slater Steel Industries, Ltd., Hamilton, Ontario, Canada. (*Small sections and bars*)

Canada Forgings Ltd., Welland, Ontario, Canada. (*Forgings*)

Dominion Foundries & Steel, Ltd., Hamilton, Ontario, Canada. (*Ingots, plates and castings*)

Interprovincial Steel and Pipe Corporation Ltd., Regina, Saskatchewan, Canada. (*Plates*)

Steel Company of Canada, Hamilton, Ontario, Canada. (*Bars and angles, plates and billets*)

Welmet Industries, Ltd., Welland, Ontario, Canada. (*Castings.*)

Trieste

Bertoli S.p.A., Officine Fratelli Bertoli fu Rodolfo, Udine, Italy. (*Castings, forgings, bars and sections*)

Orion S.p.A., Porto Industriale, Trieste, Italy. (*Forgings and castings*)

S.A.F.A.U. Ferriere Acciaierie di Udine, Udine, Italy. (*Ingots, forgings, blooms, bars and sections*)

Safog, S.A., Fonderie Officine di Gorizia, Gorizia, Italy. (*Castings*)

Valencia

Astilleros de Cadiz S.A., Factoria de Manises, Valencia, Spain. (*Castings and forgings*)

Vizcaya, Altos Hornos de, S.A., Fabrica de Sagunto, Sagunto, Spain. (*Ingots, plates, bars and sections*)

Valenciennes

Blanc-Misseron, Société Française des Aciéries de, Quievrechain (Nord), France. (*Ingots and castings*)

Chiers, Société des Hauts-Fourneaux de la, Forges de Vireux Molhain, Vireux (Ardennes), France. (*Bars and sections*)

Cockerill-Ougree-Providence, Groupe D, Usines d'Hautmont (Nord), France. (*Ingots and sections*)

Dembiermont & Cie., Maurice, Hautmont (Nord), France. (*Forgings*)

Fonderies Grandry, S.A., Mohon (Ardennes), France. (*Castings*)

Fives-Lille-Cail, Société de.
Usine de Fives, Lille (Nord), France. (*Forgings*)
Usine de Denain, Denain (Nord), France. (*Castings, ingots, forgings, blooms, bars and sheets*)

Haine - St. - Pierre et Lesquin, Aciéries de, Société Anonyme, Lesquin-lez-Lille (Nord), France. (*Castings*)

d'Hirson S.A., Aciéries, Hirson (Aisne), France. (*Castings*)

Maubeuge, Société Anonyme de la Fabrique de Fer de, Louvroil (Nord), France. (*Ingots*)

Meuse, Société Metallurgique de la, Forges et Aciéries de Stenay, Stenay, Meuse, France. (*Castings*)

Porter, H. K., (France), Aciéries Division Marpent, Marpent (Nord), France. (*Castings*)

Sambre et Meuse, Société Anonyme des Usines et Aciéries de, Usines de Feignies, Feignies (Nord), France. (*Castings*)

Union Siderurgique du Nord et de l'Est de la France, "USINOR"

Groupe A.
Usines de Denain, Denain (Nord), France. (*Ingots, plates, sections and castings*)

Groupe B.
Usines de Valenciennes, Valenciennes, (Nord), France. (*Ingots, forgings, blooms, bars and sections*)

VALLOUREC,
Usine d'Anzin—Anzin (Nord), France. (*Weldless rolled or drawn tubes*)
Usine d'Aulnoye—Aulnoye (Nord), France. (*Weldless rolled or drawn tubes*)

Valparaiso

Pacifico, Compania de Acero del, S.A., Talcahuano, Chile. (*Ingots, plates, bars and sections*)

Vancouver, B.C.

A.1. Iron & Steel Foundry Ltd., Vancouver, B.C., Canada. (*Small castings*)

C.A.E. Machinery Ltd., Vancouver B.C., Canada. (*Small castings*)

Consolidated Mining & Smelting Co. of Canada, Ltd., Trail, B.C., Canada. (*Castings*)

Esco Ltd., Port Coquitlam, B.C., Canada (*Castings*)

Letson & Burpee, Ltd., Richmond, British Columbia, Canada. (*Small castings*)

Victoria Machinery Depot Co., Ltd., Victoria, B.C., Canada. (*Castings*)

Western Canada Steel Ltd., (Vancouver Rolling Mills Ltd.,) Vancouver, B.C., Canada. (*Sections and bars*)

Venice (Mestre)

Bolzano, S.p.A. Acciaierie di, Bolzano. (*Ingots, billets, bars and forgings*)

Cantieri Navali del Tirrento e Riuniti, S.p.A., Ancona, Italy. (*Small castings*)

Flag S.p.A., Marcon (Mestre). (*Small castings*)

Gresele, Acciaierie Valbruna di Ernesto, Vicenza. (*Castings, bars, sections and forgings*)

"ITALSIDER" Alti Forni e Acciaierie Riunite Ilva e Cornigliano S.p.A., Stabilimento di Marghera. (*Rolling mills for small sections and bars*)

S.A.F.A.S.—Società Azionaria Fonderia Acciai Speciali, Tavernelle di Altavilla, Vicentina, (Vicenza). (*Castings*)

Vereeniging

Dunswart Iron & Steel Works, Ltd., Benoni, S. Africa. (*Castings, ingots, billets, and small sections*)

Scaw Metals, Ltd., Union Junction, Transvaal, S. Africa. (*Rivet bars, small rolled sections and castings*)

South African Iron & Steel Industrial Corporation, Ltd.
- "Iscor" Works, Pretoria, Transvaal, S. Africa. (*Ingots, billets and sections*)
- "Iscor" Works, Vanderbijlpark, Transvaal, S. Africa. (*Ingots, billets, slabs and plates*)

Union Steel Corporation of South Africa, Ltd., "Usco" Steel Works, Vereeniging, Transvaal, S. Africa. (*Ingots, billets, small sections, castings and rivet bars*)

Vecor Heavy Engineering, Ltd., Vanderbijlpark, Transvaal, S. Africa. (*Castings*)

Vienna

WORKS IN AUSTRIA

Böhler, Gebr., & Co., Aktiengesellschaft, Vienna.
- *Works:* Bohlerwerk, Low Austria. (*Small forgings*)
- *Works:* Bruckbach, Low Austria. (*Rolling mills for sections and bars*)
- *Works:* Kapfenberg, Styria. (*Ingots, castings, forgings, bars and plates*)

Hubner-Vamag, Vereinigte Armaturenfabriken, Aktiengesellschaft, Vienna, Austria. (*Castings*)

Klinger, Rich., Aktiengesellschaft, Gumpoldskirchen, near Vienna. (*Small castings*)

Österreichisch - Alpine Montangesellschaft, Vienna.
- *Works:* Donawitz, Styria. (*Sections and strip*)
- *Works:* Kindberg, Styria. (*Rolling mills for small sections, bars and strip*)
- *Works:* Traisen, Low Austria. (*Castings*)

Vienna—*continued*

Schoeller-Bleckmann Stahlwerke A.G., Vienna.
- *Works:* Muerzzuschlag-Hoenigsberg, Styria. (*Bars*)
- *Works:* Ternitz, Low Austria. (*Castings, forgings and bars*)

Steirische Gusstahlwerke, A.G., Vienna.
- *Works:* Judenburg, Styria. (*Forgings and bars*)

Vereinigte Österreichische Eisen-und-Stahlwerke A.G.
- *Works:* Liezen, Styria. (*Ingots for forgings, castings*)
- *Works:* Linz a.d. Donau, Upper Austria. (*Plates, forgings and castings*)

Waagner-Biro Aktiengesellschaft, Vienna, Austria.
- *Works:* Werk C., Vienna. (*Castings*)

WORKS IN CZECHOSLOVAKIA

Nová hut Klementa Gottwalda, národni podnik (New Metallurgical Works of Klement Gottwald, National Corporation), Ostrava - Kunčice. (*Ingots and forgings*)

Škoda, Oborový Podnik, Plzeň. (*Castings and forgings*)

Švermore Železiarne, národný podnik (Sverma's Iron Works, National Corporation), Podbrezová. (*Ingots and plates*)

Třinecké železárny velké Řijnové socialistické revoluce, národni podnik (Třinec Iron Works Great Socialistic October Revolution National Corporation), Třinec. (*Ingots, sections, bars and castings*)

Válcovny Trub a Železarny, národni podnik, (Tube Rolling Mills and Iron Works, National Corporation), Chomutov.
- *Works:* Železárny Bílá Cerkev, národni podnik, Hrádek u Rokycan. (*Ingots and bars*)
- *Works:* Chomutov. (*Seamless steel tubes*)

Vítkovické Železárny Klementa Gottwalda, národni podnik (The Vitkovice Steel Works Klement Gottwald, National Corporation), Ostrava 10. (*Castings, forgings, plates, sections, bars and seamless tubes*)

Zelezárny a drátovny Bohumin, národni podnik (Iron Works & Wire Works Bohumin, National Corporation), Bohumin, Czechoslovakia. (*Small sections and bars*)

WORKS IN HUNGARY

Ganz-Mavag Mozdony Vagon es Gepgyar, Budapest. (*Castings and forgings*)

K.G.M. Altalanos Gepipari Igazgatóság, Budapest.
- *Works:* Öntödei Vallalat 1. sz. Gyára, Budapest. (*Castings*)

K.G.M. Jarmuipari Igazgatóság, Budapest.
- *Works:* Magyar Vagon-és Gépgyár, Györ. (*Castings*)

K.G.M. Vaskohászati Igazgatóság, Budapest.
- *Works:* Lenin Kohászati Müvek, Miskolc-Diósgyör. (*Ingots, slabs, sections, bars, castings and forgings*)
- *Works:* Dunai Vasmü, Dunaujváros. (*Ingots, slabs and plates*)
- *Works:* Dunai Vasmü, Lörinci Hengermüve, Budapest. (*Rolling mill for plates*)
- *Works:* Ozdi Kohászati, Uzemek, Ozd. (*Ingots, slabs, plates, sections and bars*)

Vigo

Aceros de Galicia, Vigo, Spain. *(Castings)*

Whyalla

Broken Hill Proprietary Co., Ltd., Iron and Steel Works, Whyalla, S. Australia. *(Ingots, castings, bars and sections)*

Winterthur

Fischer, George, Ltd., Schaffhausen Switzerland. *(Castings)*

Fonderie de Fer et d'Acier Biel, Switzerland. *(Castings)*

Sulzer Bros., Ltd., Winterthur, Switzerland. *(Castings and forgings)*

Von Roll A.-G., Gerlafingen, Switzerland. *(Ingots, round bars and forgings)*

Yokohama

Ando Iron Works Co., Ltd., Tokyo, Japan. *(Small forgings)*

Azuma Steel Casting Co. Ltd., Takaoka Works, Takaoka, Japan. *(Castings)*

Azuma Steel Works Ltd.
- Azuma Plant, Tokyo, Japan. *(Ingots for plate)*
- Senju Plant, Tokyo, Japan. *(Rolling mills for plates)*

Daido Steel Co., Ltd., Shibukawa Works, Shibukawa, Japan. *(Ingots, small forgings and bars)*

Date Seiko Co., Ltd., Tokyo, Japan. *(Castings)*

Fukushima Seiko Co., Ltd., Fukushima, Japan. *(Castings)*

Funabashi Steel Works Ltd., Funabashi City, Chiba Prefecture, Japan. *(Ingots and flat bars)*

Hakodate Dock Co., Ltd., Hakodate Shipyard, Hakodate, Japan. *(Small castings and forgings)*

Haneda Pipe Works Co., Ltd., Tokyo, Japan. *(Seamless tubes)*

Hatakeyama Iron Works Co., Ltd., Komatsugawa. *Works:* Tokyo, Japan. *(Small forgings)*

Hitachi Ltd.
- Hitachi Works, (Yamate Factory) Hitachi-shi, Japan. *(Castings)*
- Katsuta Works, Katsutashi, Inaragi-ken. *(Ingots, forgings and castings)*

Hokuriku Kogyo Co., Ltd., Sanjo Plant, Sanjo, Niigata Prefecture, Japan. *(Small forgings)*

Ishikawajima-Harima Heavy Industries Co., Ltd., Tokyo, Japan. *(Ingots, forgings and castings)*

Japan Special Steel Co., Ltd., Tokyo, Japan. *(Ingots, forgings, blooms, billets and bars)*

Japan Steel Works Ltd., Muroran Works, Muroran, Japan. *(Ingots, forgings, castings and plates)*

Joban Machinery Co. Ltd., Uchigo Factory, Fukushima Prefecture, Japan. *(Castings)*

Jonan Ironworks Co., Ltd., Haneda Works, Tokyo, Japan. *(Small forgings)*

Kakegawa Endo Iron Works Co., Ltd., Kakegawa, Japan. *(Forgings)*

Yokohama—*continued*

Kanto Special Steel Works Ltd., Fujisawa, Kanagawa Pref., Japan. *(Forgings)*

Kawaguchi Kinzoku Kogyo Kabushiki Kaisha, Kawaguchi, Japan. *(Castings)*

Kawasaki Heavy Ind. Ltd., Crushing Plant Mfg. Division, Japan. *(Castings)*

Kawasaki Steel Corporation, Chiba Works, Chiba, Japan. *(Slabs and plates)*

Kureha Seitetsu Co., Ltd., Toyama, Japan. *(Ingots)*

Mitsubishi Heavy Industries Ltd., Yokohama Shipyard and Engine Works, 1-1 Midoricho, Nishi-ku, Yokohama, Japan. *(Castings)*

Mitsubishi Metal Mining Co., Ltd., Okegawa Plant, Saitama Prefecture, Japan. *(Small castings)*

Mitsubishi Steel Manufacturing Co., Ltd., Tokyo, Japan.
- Hirota Works, Fukushima Pref. *(Castings)*
- Tokyo Steel Works. *(Billets, bars and small forgings)*

Nakayama Steel Products Co. Ltd., Tsurumi Works, Tsurumi, Yokohama, Japan. *(Ingots and plates)*

Nippon Chuzo Kabushiki Kaisha, Kawasaki, Japan. *(Castings)*

Nippon Kokan Kabushiki Kaisha.
- Asano Dockyard, Yokohama, Japan. *(Small forgings)*
- Keihin Iron Works.
  - Mizue Plant. *(Plates up to 12,5 mm in thickness)*
  - Tsurumi Plant. *(Ingots and plates)*
  - Tubular & Structural Products Dept. *(Tubes, bars and sections)*

Nippon Stainless Steel Co., Ltd., Naoetsu Works, Niigata, Japan. *(Ingots, forgings, castings and plates)*

Nippon Steel Corporation.
- Kamaishi Works, Kamaishi, Japan. *(Sections and bars)*
- Kimitsu Works, Kimitsu, Japan. *(Ingots and plates)*
- Muroran Works, Hokkaido, Japan. *(Billets, sections and bars)*
- Tokyo Works, Japan. *(Rolling mills for weldless, rolled or drawn tubes)*

Nippon Yakin Kogyo Co., Ltd., Kawasaki, Japan. *(Ingots, forgings, bars and thin plates)*

Nittoku Metal Industry Co., Ltd., Tokyo, Japan. *(Small forgings)*

Oji Steel Co. Ltd., Kita-Ku, Tokyo, Japan. *(Flat bars)*

Osaka Shipbuilding Co., Ltd., Taira Steel Works, Taira City, Fukushima Prefecture, Japan. *(Castings)*

Pacific Metals Company Limited.
- Naoetsu Factory, Naoetsu, Niigata, Japan. *(Ingots and castings)*
- Toyama Factory, Toyama City, Japan. *(Ingots and forgings)*

Yokohama—*continued*

Riken Tanzo Co., Ltd., Maebashi Plant, Maebashi, Japan. (*Small forgings*)

Shimizu Forge Co., Ltd., Tokyo, Japan. (*Forgings*)

Shin Nippon Tanko K.K., Kawasaki, Japan. (*Small forgings*)

Sunnan Iron Works Co., Ltd., Yaizu, Japan. (*Forgings*)

Takasaki Metal Industry Co., Ltd., Takasaki Plant, Takasaki, Japan. (*Small castings*)

Tohoku Special Steel Works Ltd., Sendai, Japan. (*Ingots, small forgings, billets and bars*)

Tokushu Seiko (Special Steel Mfg.) Co., Ltd., Kawasaki *Works:* Kawasaki, Japan. (*Ingots, forgings and bars*)

Yokohama—*continued*

Tokyo Kikai Kabushiki Kaisha, Oshima Cast Steel *Works:* Tokyo, Japan. (*Castings*)

Tokyo Precision Forging Works Co., Ltd. (Tokyo Seitan Works Co., Ltd.), Ichikawa City, Chiba Prefecture, Japan. (*Small forgings*)

Tokyo Steel Casting Co., Ltd., Tokyo, Japan. (*Castings*)

Tokyo Tankosho Co., Ltd., Kawasaki Factory, Kawasaki, Japan. (*Small forgings*)

Topy Industries, Ltd., Tokyo Works, Tokyo, Japan. (*Sections*)

Toshiba Steel Co., Ltd., Tokyo, Japan. (*Sections and ingots for forging and plates*)

Watanabe Steel Works Co., Ltd., Tokyo, Japan. (*Castings*)

MANUFACTURERS OF ALUMINIUM ALLOYS

The following establishments have complied with the conditions contained in P 12 to P 14 of the Rules and are recognised by the Committee for the manufacture of aluminium alloys for shipbuilding purposes.

United Kingdom

Alcan Industries Ltd., Banbury. (*Aluminium alloys and products*)

Alcan Industries Ltd., Newport, Mon. (*Aluminium alloys and products*)

ALCOA Manufacturing (G.B.) Limited. (*Aluminium alloys and products*)

Aluminium Wire & Cable Co., Ltd., Port Tennant, Swansea. (*Aluminium alloys and products*)

Birmetals Ltd., Quinton, Birmingham. (*Aluminium alloys and products*)

James Booth Aluminium Ltd., Birmingham. (*Aluminium alloys and products*)

British Aluminium Co., Ltd., Falkirk. (*Aluminium alloys and products*)

British Aluminium Co., Ltd., Redditch Works, Birmingham. (*Aluminium alloys and products*)

British Aluminium Co., Ltd., Rheola Works, South Wales. (*Aluminium alloys and products*)

British Aluminium Co., Ltd., Bank Quay, Warrington. (*Aluminium alloys and products*)

High Duty Alloys Ltd., Winscales, Workington. (*Aluminium alloys and products*)

E. & E. Kaye, Ltd., Enfield, Middlesex. (*Aluminium alloys and products*)

Austria

Vereinigte Metallwerke Ranshofen-Berndorf A.G., Braunau am Inn. (*Aluminium alloys and products*)

Belgium

Ateliers Remi Claeys Lichtervelde. (*Aluminium alloy products*)

S.A. Sidal, Société de l'Aluminium, Duffel. (*Aluminium alloys and products*)

Sidal S.A., Burcht. (*Aluminium alloy products*)

Société Franco-Belge des Laminoirs et Tréfileries d'Anvers "LAMITREF", Hemiksem. (*Aluminium alloy rivet bars*)

Canada

Aluminum Company of Canada, Ltd. (No. 1 Plant), Shawinigan Falls, Quebec. (*Aluminium alloy products*)

Aluminum Company of Canada, Ltd., Kingston, Ont. (*Aluminium alloys and products*)

Reynolds Extrusion Co., Ltd.

- Plant No. 1, St. Therese, Quebec. (*Aluminium alloys and products*)
- Plant No. 4, Oshawa, Ontario. (*Aluminium alloys and products*)

Denmark

Aluminord A/S, Glostrup, Copenhagen. (*Aluminium alloys and products*)

Finland

Oy Nokia A.B., Finska Kabelfabriken, Pikkala. (*Aluminium alloys and products*)

France

Société Cegedur G.P.

- Le Blanc - Mesnil 93. (*Aluminium alloys and products*)
- Chambery (Savoie). (*Aluminium alloy products*)
- Faremoutiers (Seine & Marne). (*Aluminium alloys and products*)
- Issoire (Puy de Dome). (*Aluminium alloys and products*)
- Montreuil Belfroy. (*Aluminium alloy products*)
- Rive de Gier (Loire). (*Aluminium alloy products*)

Soc. Cuivre et Alliages, Usine a Ham (Somme). (*Aluminium alloys and products*)

Germany

Aluminiumwalzwerke Singen G.m.b.H., Singen (Hohentwiel). (*Aluminium alloys and products*)

Otto Fuchs, Meinerzhagen. (*Aluminium alloys and products*)

Kabel-und Metallwerke Gutehoffnungshütte Aktiengesellschaft, Osnabrück. (*Aluminium alloys and products*)

Kaiser Aluminium-Werke G.m.b.H., Koblenz. (*Aluminium alloys and products*)

Reynolds Aluminiumwerke G.m.b.H., Nachrodt. (*Aluminium alloys and products*)

Vereinigte Deutsche Metallwerke A.G., Frankfurt-Heddernheim. (*Aluminium alloys and products*)

Vereinigte Leichtmetall-werke G.m.b.H., Bonn. (*Aluminium alloys and products*)

Vereinigte Leichtmetall-werke G.m.b.H., Hannover. (*Aluminium alloys and products*)

Holland

N.V. Nederlandsche Aluminium Maats., Utrecht. (*Aluminium alloys and products*)

India

Indian Aluminium Co., Ltd., Alwaye, Kerala State. (*Aluminium alloys and products*)

Indian Aluminium Co., Ltd., Howrah, West Bengal. (*Aluminium alloys and products*)

Italy

Lavorazione Leghe Leggere, Marghera (Venice). (*Aluminium alloys and products*)

Montecatini Divisione Alluminio e Metalli, Feltre (Belluno) Works, Milan. (*Aluminium alloys and products*)

Trafilerie e Laminatoi di Metalli S.p.A., Milan. (*Aluminium alloys and products*)

Japan

Furukawa Aluminum Co., Ltd., Tokyo. (*Aluminium alloys and products*)

Kobe Steel Ltd., Chofu Plant, Shimonoseki. (*Aluminium alloys and products*)

Sumitomo Light Metal Industries Ltd., Nagoya Works, Nagoya. (*Aluminium alloys and products*)

Norway

Alprofil, Raufoss. (*Aluminium alloy products*)

A/S Nordisk Aluminiumindustri, Oslo.
Hoyanger Works. (*Aluminium alloys*)
Holmestrand Works. (*Aluminium alloy products*)

Poland

Walcownie Metali "Dziedzice".
Czechowice-Dziedzice. (*Aluminium alloy sections, bars and tubes*)
Zaklady Metali Lekkich "Kety", Kety. (*Aluminium alloy, sections and tubes*)

Spain

Aluminio de Galicia S.A.
Amorebieta Works. (*Aluminium alloys and products*)
La Coruña Works. (*Aluminium alloys and products*)
Sabinanigo Works. (*Aluminium alloys and products*)

Aluminio Iberico, S.A., Alicante. (*Aluminium alloys and products*)

Eduardo K. L. Earle, Lejona. (*Aluminium alloys and products*)

Sweden

A/B Svenska Metallverken, Finspong. (*Aluminium alloys and products*)

Switzerland

Aluminium Press & Walzwerk A. G., Munchenstein. (*Aluminium alloys and products*)

Aluminium S.A., Menziken. (*Aluminium alloys and products*)

Swiss Aluminium Ltd., Chippis. (*Aluminium alloys and products*)

U.S.A.

Alcan Aluminum Corporation, Fairmount, West Virginia, U.S.A. (*Aluminium alloys and products*)

Alcan Aluminum Corporation, Oswego, New York. (*Aluminium alloys and products*)

Yugoslavia

Tvornica Lakih Metala "Boris Kidric", Sibenik. (*Aluminium alloys and products*)

MANUFACTURERS OF STEEL WIRE ROPE

The following establishments have complied with the conditions contained in P 9 of the Rules and are recognised by the Committee for the manufacture of steel wire ropes.

United Kingdom

Binks Bros. Ltd., London.
British Ropes Ltd., Doncaster.
British Ropes Ltd., Gateshead-on-Tyne.
British Ropes Ltd., Glasgow.
British Ropes Ltd., London.
British Ropes Ltd., Retford.
British Ropes Ltd., (Webster Ropes), Sunderland.
Bruntons (Musselburgh) Ltd., Musselburgh.
Crawhall, Joseph, & Sons Ltd., Gateshead-on-Tyne.
Dawson & Usher Ltd., Sunderland.
Excelsior Ropes Group,
Comprising:—
Excelsior Ropes Ltd.,
Geo. Elliott & Co., Ltd.,
D. Morgan Rees & Sons Ltd.,
} Western Avenue, Cardiff.
Firth Cleveland Ropes Ltd., Sheffield.
Frew Bros. Ltd., Coatbridge.
Glover Bros. (Mossley) Ltd., near Manchester.
The Gourock Ropeworks, Glasgow.
Hall's Barton Ropery Co., Ltd., Hull.
Hood Haggie, R., & Son, Ltd., Newcastle upon Tyne.
John I. Hopper Ltd., Thornaby-on-Tees.
Latch & Batchelor Ltd., Birmingham.
Martin, Black & Co. (Wire Ropes), Ltd., Coatbridge.
Overton Bros. Wire Ropes Ltd., Hull.
Rylands Bros., Ltd., Warrington.
Scottish Wire Rope Co., Ltd. (John I. Hopper Ropes), near Glasgow.
Shaw, John, Ltd., Worksop.
Whitecross Co., Ltd., Warrington.

Argentina

Establecimientos Metalurgicos Santa Rosa S.A., Buenos Aires.
Felix Simon S.A.C.I.F., Buenos Aires.

Australia

Australian Wire Rope Works Pty. Ltd.,Newcastle,N.S.W.

Austria

Felten & Guilleaume Fabrik Elektrischer Kabel, Vienna and Bruck an der Mur.
Joh. Pengg, Draht-und Walzwerke, Thörl bei Aflenz, Steiermark.
St. Egydyer Eisen-und Stahl-Industrie-Gesellschaft, St. Aegyd am Neuwalde.
Teufelberger, K., Drahtseilwerke, Wels, Upper Austria.

Belgium

Anglo-Continental Ropes, Gilly.
"Cabcord" (Société Générale de Cablerie et Corderie), Hamme s/durme.
"Cabcord" (Société Générale de Cablerie et Corderie), Renory.
Cableries Namuroises S.A., Jambes.
Cableries & Corderies du Hainaut, S.A., Dour, near Mons.
Gonzalez Cock S.A., Lokeren.
Le Lis, S.A., Hamme-sur-Durme.
Van Praet-Dansaert, Baasrode.

Brazil

Cia. Industrial e Mercantil de Artefatos de Ferros, Sao Paulo.

Canada

Greening Donald Ltd., Hamilton, Ontario.
Greening Donald Ltd., Midland, Ontario.
Wire Rope Industries of Canada Ltd. (Canada Wire Ropes Ltd.), Smith Falls, Ontario.
Wire Rope Industries of Canada Ltd., Vancouver, B.C.

Chile

Productos de Acero, Santiago.

Denmark

Jacob Holm & Sønners Fabriker, A/B., Copenhagen.
Randers Rebslaaeri A/S., Randers.

Finland

Oy Teräsköysi, Hämevaara, Nr. Helsinki.

France

Cablerie Saint-Moritz, Reichshoffen (67).
Societe Anonyme des Hautes Fourneaux de la Chiers, Departement des Trefileries & Cableries, Le Havre.
Laminoirs-Tréfileries-Cableries de Lens, Lens.
Tréfileries de Chatillon-Gorcy S.A. Usine de Sainte-Colombe-sur Seine-21.

Germany

Ahlers, C. G., Hanf-u. Drahtseilfabrik, Bremerhaven.
Arbed S.A., Arbed-Felten & Guilleaume, Vereinigte Drahtwerke, Koln-Mulheim.
Bertram, J., K.G. Drahtseilwerk, Soest.

Germany—*continued*

Braucke, Adolf vom. A.G., Ihmerterbach.
Bremer Draht-und Seilindustrie G.m.b.H., Bremen-Hemelingen.
Drahtseilerei Gustav Kocks, Mülheim (Ruhr)—Broich.
Drahtseilwerke G.m.b.H., Bremerhaven.
Gempt, J. H., Lengerich/Westf.
Hamburger Drahtseilerei G.m.b.H., Bad Oldesloe.
Georg Heckel G.m.b.H., Draht-und Drahtseilfabrik, Saarbrucken.
Hüttenwerk Oberhausen A.G., Werk Gelsenkirchen vorm. Boecker & Comp.
Klockner - Werke A.G. Dusseldorfer Drahtindustrie, Dusseldorf.
Norddeutsches Drahtseilwerk, A. Brinkmann, Syke.
Seilindustrie Ernst Deifuss, Unna/Westf.
Seilwerke Heinrich Puth K.G., Blankenstein, Ruhr.
Vereinigte Drahtseilwerke G.m.b.H., Dortmund.
Vornbäumen, J. & W., K.G., Bad Iburg.
Westdeutsche Seilindustrie Paul Stoessel, Osterrath b/Dusseldorf.
Westfälische Drahtindustrie, Hamm.
Westfälische Union A.G., Lippstadt.
Westfälische Union A.G., für Eisen und Drahtindustrie, Drahtseilwerk Oesede.
Westfalische Union, Werk Neheim.
Wolf, Gustav, Gütersloh.

Greece

Greek German Wire Rope Industry, Nea Ionia, Volos.

Holland

Staaldraadkabel & Herculestouwfabriek J. C. den Haan, Gorinchem.
Vereenigde Touwfabrieken, Leiderdorp.

Hong Kong

Hong Kong Steel Ropes Ltd., Kowloon.

India

Bombay Wire Ropes Ltd., Bombay.
Eldee Wire Ropes Pvt. Ltd., Bombay.
Fort William Company Limited, Steel Wire & Rope Division, Calcutta.
Mohatta & Heckel Ltd., Khopoli.
South India Wire Ropes Ltd., Kerala State.
J. K. Steel Ltd., Calcutta.
United Wire Ropes Ltd., Bombay.
Usha Martin Black (Wire Ropes) Ltd., Asian Wire Ropes, Ranchi.

Israel

Wire Rope Works Messilot Ltd., Doar Na Gilboa.

Italy

Acciaierie Ferriere Lombarde Falck, Sesto San Giovanni.
Giuseppe & Fratello Redaelli S.p.A.,—Gardone val Trompia (Brescia), Brescia.
Industrie Metallurgiche Piemontesi, Susa.
Ing. Guido Scolari (Soc., Acc., Semp.), Milan.
Societa Italiana Derivati Vergella, S.p.A. (D.E.R.I.V.E.R.), Sezione di Torre Annuziata.
Stabilimenti G. Fornara & Co., Turin.

Japan

Ako Rope & Wire Mfg. Co., Ltd., Sakoshi.
Asahi Wire Rope Manufacturing Co., Ltd., Osaka
Daido Wire Rope Mfg. Co., Ltd., Osaka.
Igeta Wire Rope Co. Ltd., Izumisano.
Kasuga Seiko K.K., Osaka.
Kawasaki Steel Corporation, Wire Rope and Welding Rod Plant, Chiba.
Kokoku Iron & Steel Wire Mfg. Co., Ltd., Niigata.
Kokoku Iron & Steel Wire Mfg. Co., Ltd., Osaka.
Kokoku Iron & Steel Wire Mfg. Co., Ltd., Tokyo.
Nankai Sensyu Steel Wire & Rope Co., Ltd., Kaizuka.
Nippon Steel Wire & Wire Rope Co., Ltd., Osaka.
Nishida Wire Rope Mfg. Co., Ltd., Osaka.
Shinko Wire Co., Ltd., Amagasaki.
Showa Wire Rope Mfg. Co., Ltd., Osaka.
Tatsumi Rope Mfg. Co., Ltd., Osaka.
Teikoku Sangyo Co., Ltd., Osaka.
Tokyo Rope Mfg. Co., Kokura.
Tokyo Rope Mfg. Co., Osaka.
Tokyo Rope Mfg. Co., Ltd., Ibaragi Prefecture.

Mexico

Cables Mexicanos S.A., Mexico.

Norway

Norsk Staaltaugfabrik, Trondheim.
Stål og Tau A/S Avd. Mandal, Mandal.
Stål og Tau A/S Avd. Tonsberg Reperbane.

Poland

Fabryka Lin i Drutu, Bytom Karb.
Sosnowiecka Fabryka Lin i Drutu, Sosnowiec.

Portugal

Cordoaria Lisbonense, Lisbon.
Quintas and Quintas, Povoa do Varzim.
Rodrigues d'Oliveira, M., Sa & Fos, Ltda., Oporto.

South Africa

African Wire Ropes Ltd., Johannesburg.

Subsidiary Companies

Haggie, Son & Love (1936) Ltd., Jupiter Rope Works, Cleveland.

Rand Ropes, Ltd., Germiston.

Spain

Forjas y Alambres de Cadagua, Bilbao.

Franco Espanola de Alambres, S.A., Bilbao.

"Nueva Montana Quijano", S.A., Santander.

Trenzas y Cables de Acero S.A., Barcelona.

Sweden

Garphytte Bruks A/B., Garphyttan.

Gunnebo Bruks A/B Varberg.

Sweden—*continued*

Lesjofors A/B., Lesjofors.

Stallinefabriken, David Ahlquist A/B., Roslags-Nasby.

Uddeholms A/B., Blombacka Bruk, Lindfors.

United Arab Republic

Copper Works, Hagar el Nawatia, Alexandria.

United States of America

The Wire Rope Corporation of America, St. Joseph, Missouri.

Yugoslavia

Novosadska Fabrika Kabela, Novi Sad.

"Otocanka", Zadar.

PROVING ESTABLISHMENTS

The following establishments have been recognised by the Committee for the testing of anchors and chain cables in accordance with the Society's Rules. Anchors and chain cables intended for ships of United Kingdom Registry must be tested at establishments certified under the terms of the United Kingdom Anchors and Chain Cables Act, 1967.

Argentine

Direccion General de Administracion Naval, Buenos Aires, Argentine.

Australia

Falkiner Chains Pty. Ltd., Brisbane, Queensland (for testing chain cables up to 250 tons).

Austria

Ferdinand Freiherr v. Helldorff & Otto Rothart Kettenwerk Brückl, Brückl, Carinthia.

Steirische Kettenfabriken Pengg-Walenta Kommanditgesellschaft, Werk Hansenhütte, Kapfenberg-Hansenhütte, Styria.

Belgium

Adh. Demanet, Gosselies (for testing chains up to 300 tons).

Béliard, Murdoch & Co., Antwerp (for testing anchors and chain cables up to 100 tons).

Mercantile Marine Engineering & Graving Dock Co., Antwerp.

Usines et Aciéries Allard S.A., Mont-sur-Marchienne (for testing anchors only).

Brazil

Acos Villares, Sao Paulo (for testing anchors only).

Canada

Canada Chain & Forge Co., Ltd., Granville Island Vancouver, B.C.

Dominion Chain Co., Ltd., Stratford, Ontario.

Drummond, McCall & Co., Ltd., Quebec.

Finland

Fiskars A.B., Loimaa.

Oy Wärtsilä A/B., Dalsbruk, Helsingfors (for testing anchors up to 150 tons and chain cables up to 250 tons).

France

Carlier et Cie., St. Amand-les-Eaux (Nord).

Davaine, Fils et Cie., St. Amand-les-Eaux (Nord) (for testing chain cables up to 132 tons).

Ets. Marit, St. Amand-les-Eaux (Nord).

Manufacture de Chaines et Ancres de Saint-Amand, Etablissements Sirot-Mestreit and Dorémieux Reunis, Saint-Amand-les-Eaux (Nord).

Paoli, J., & Co., Marseilles.

Société des Forges des Fresnes, Fresnes-sur-Escaut (Nord) (for testing chain cables up to 150 tons).

Veille, A., & Co., Le Havre.

Germany

Blohm & Voss A.G., Hamburg.

Dortmunder Kettenfabrik Bernhard Mester, Wetterstr. 10, Dortmund.

Duisberger Kettenfabriek und Hammerwerk, H d'Hone, Duisburg.

Eisenwerk und Apparatebau Gebr. Knauer, Abteilung Hammerwerk Heuss (Mannheim).

Fröndenberger Kettenfabrik, Heinrich Prünte, Frondenberg-Ruhr (for testing chain cables up to 120 tons.)

Wilhelm Gröhnke, Hamburg.

Hoesch Hüttenwerke A.G., Werk Phoenix Hörde, Dortmund-Hörde (for testing anchors only).

Howaldtswerke A.G., Hamburg.

Joto-Werk Josef Topp, Kettenfabrik, Warmen (Ruhr).

Kettenfabrik Kalthof, August Thiele; and August Thiele G.m.b.H., Fabrik für Ketten und Kettenforderer, Kalthof, near Schwerte-Ruhr.

Kettenwerke Schlieper, Grune, Westphalia.

Theile, J. D., Schwerte-Ruhr.

Holland

Koninklijke Nederlandsche Grofsmederij, Leiden.

N.V. Anker-& Kettingfabriek "Schiedam" (*Managing Director:* P. Th. Verhoeff), Schiedam.

Hong Kong

The Taikoo Dockyard & Engineering Co. of Hong Kong Ltd.

Hungary

Kohó-és Gépipari Miniszterium, Budapest, Works: Késziszerszámgyár, Budapest.

India

The Commissioners for the Port of Calcutta, Calcutta.

Italy

Acciaieria e Ferriera del Caleotto S.p.A., Lecco.

Acciaierie Weissenfels, Catenificio, Fusine di Valromana, Udine (for the testing of small chains only).

Neptunia S.r.L., Genoa.

Japan

Hamanaka Chain Manufacturing Co., Ltd., Himeji.

Japan Mechanical Chain Manufacturing Co., Ltd., Osaka.

Kotobuki Kogyo Co. Ltd., Hiro Works, Kure.

Koyo Chain Manufacturing Co., Ltd., Osaka.

Onomichi Anchor Manufacturing Co., Ltd., Onomichi (for testing anchors only).

Osaka Chain & Machinery Manufacturing Co., Ltd., Kaizuka Works, Osaka.

Toa Seisa Co., Ltd., Himeji.

Tokyo Chain & Anchor Co., Ltd., Tokyo.

Malta

Malta Drydocks, The Docks, Malta G.C.

Norway

Norsk Kjettingindustri A/S, Mandal.

Poland

Stocznia im. Komuny Paryskiej, Gdynia.

Zaklady Mechaniczne im. Gen. K. Swierczewskiego, Elblag.

South Africa

Cotts Steel Industries (Pty.) Ltd., Johannesburg.

McKinnon Chain (South Africa) (Pty.) Ltd., Vereeniging, Transvaal.

Spain

Cadenas y Forjádos, S.A., J. M. Olavarri, Bilbao. *Works:* Lejona, Bilbao.

Don Ciriaco Rodriguez Dorado, Barcelona (for testing chain cables up to 30 tons).

Forjas de San Martin de Pedro Framis, Barcelona (for testing chains up to 16 tons).

Vicinay, S.A., Deusto.

Sweden

Gunnebo Bruks Aktiebolag, Gunnebobuck, Västervik (for testing chains up to 75 tons).

Jarnbirger A/B, Orsa.

Ramnäs Bruks Aktiebolag, Ramnäs.

Statens Provningsanstalt (Government Establishment), Stockholm.

Ström-Ljusne Aktiebolag, Ljusne.

Turkey

Gemi Zincir Sanayii Kollektif Şirketi, Istanbul.

United Kingdom

British Tayco Chain Co., Ltd., Brierley Hill, Staffs.

Brown, Lenox & Co., Ltd., Pontypridd, Mon.

Lloyd's British Testing Co. Ltd., Low Walker-on-Tyne, Northumberland.

Lloyd's British Testing Co. Ltd., Netherton, (near Dudley), Worcs.

Lloyd's Scottish Testing Co. Ltd., Burnbank, Hamilton, Lanark.

Lloyd's South Wales Testing House Co. Ltd., Cardiff, Glam.

Norbrit-Pickering Ltd., Coatbridge, Lanark.

United States

Baldt Anchor Chain & Forge Division of Baldt Corp., Chester, Pa.

Baldt Anchor Chain & Forge Division of Baldt Corp., Fieldsboro, N.J.

Johnson-Farmer Chain Co., Lebanon, Pa.

Washington Chain & Supply Co., Seattle, Washington.

Yugoslavia

Tovarna Verig, Lesce pri Bledu.

ELECTRICALLY WELDED STEEL CHAIN CABLES

and

CAST STEEL CHAIN CABLES

The following establishments have complied with the requirements for manufacture of electrically welded and cast steel chain cables and have been recognised by the Committee:—

GRADE U 1 (a) *Flash butt welded chain cables of mild steel having a tensile breaking strength of* 31 *to* 41 *kg/mm*^{2} (19·7 *to* 26·0 *ton/in*^{2}).

GRADE U 1 (b) *Flash butt welded chain cables of mild steel having a tensile breaking strength of* 41 *to* 50 *kg/mm*^{2} (26·0 *to* 31·7 *ton/in*^{2}).

GRADE U 2 (a) *Flash butt welded or drop forged special quality steel having a tensile breaking strength of* 50 *to* 65 *kg/mm*^{2} (31·7 *to* 41·3 *ton/in*^{2}).

GRADE U 2 (b) *Cast steel having a minimum tensile breaking strength of* 50 *kg/mm*^{2} (31·7 *ton/in*^{2}).

GRADE U 3 (a) *Flash butt welded or drop forged extra special quality steel having a minimum tensile breaking strength of* 70 *kg/mm*^{2} (44·4 *ton/in*^{2}).

GRADE U 3 (b) *Cast steel having a minimum tensile breaking strength of* 70 *kg/mm*^{2} (44·4 *ton/in*^{2}).

NOTE: Before acceptance on classed ships chain cables must be tested on a chain cable testing machine recognised by the Society.

FIRM	GRADE & TRADE NAME (IF ANY)	MAXIMUM DIAMETER	SURVEYING DISTRICT
United Kingdom			
Beal & Son (Cable Makers) Ltd., Cardiff.	U 1 (a), U 1 (b) & U 2 (a)	4 in	Cardiff
	U 2 (a) (Meyer, Roth and Pastor)	$1\frac{3}{8}$ in	
Bradney Chain & Engineering Co. Ltd., Quarry Road, Dudley, Worcs.	U 1 (b) (Short link)	$\frac{1}{2}$ in	Birmingham
The British Tayco Chain Co Ltd., Brierley Hill, Staffs.	U 1 (a) & U 1 (b)	$4\frac{1}{8}$ in	Birmingham
	U 2 (a) (Tayco)	$4\frac{1}{8}$ in	
	U 2 (a) (New Process Tayco)	$3\frac{5}{16}$ in	
	U 3 (a)	4 in	
Brown, Lenox & Co. Ltd., Pontypridd.	U 2 (b)	3 in	Cardiff
Griffin-Woodhouse Ltd., Cradley Heath, Staffs.	U 2 (a)	$2\frac{3}{16}$ in	Birmingham
Norbrit-Pickering Ltd., Wishaw, Lanarkshire.	U 1 (a), U 1 (b) & U 2 (a)	$4\frac{1}{8}$ in	Glasgow
	U 3 (a)	$4\frac{1}{2}$ in	
Parsons Chain Co. Ltd., Stourport-on-Severn.	U 1 (a), U 1 (b) & U 2 (a) (Short link)	$1\frac{1}{4}$ in	Birmingham
Wheway Watson Ltd., Bellshill, Lanarkshire.	U 2 (a) (Short link)	$\frac{7}{8}$ in	Glasgow
Wheway Watson Ltd., Walsall Works, Walsall.	U 1 (a)	$\frac{7}{8}$ in	Birmingham
	U 1 (b) (Short link)	$\frac{11}{16}$ in	

Firm	Grade & Trade Name (if any)	Maximum Diameter	Surveying District
Australia			
Falkiner Chains Pty. Ltd., Brisbane.	U 1 (a) U 1 (b) (Short link) U 2 (a)	$3\frac{3}{16}$ in $\frac{3}{4}$ in $3\frac{3}{16}$ in	Brisbane
Austria			
Ferdinand Freiherr v. Helldorff & Otto Rothart Kettenwerk Brückl, Brückl.	U 1 (a) (Short link)	26 mm	Vienna
Steirische Kettenfabriken Pengg-Walenta Kommanditgesellschaft, Styria.	U 1 (a) U 1 (b) & U 2 (a)	44 mm 41 mm	Vienna
Belgium			
Adh-Demanet, Gosselies.	U 1 (a), U 1 (b) & U 2 (a)	76 mm	Antwerp
Finland			
Fiskars A.B., Loimaa.	U 1 (a)	36 mm	Abo
Oy Wartsilä A.B., Dalsbruk Works, Dalsbruk.	U 1 (a), U 1 (b) & U 2 (a)	64 mm	Abo
France			
M. Carlier & Cie., St.-Amand-les-Eaux (Nord).	U 1 (a) & U 1 (b)	30 mm	Valenciennes
Davaine Fils et Cie., St.-Amand-les-Eaux (Nord)	U 1 (a) & U 1 (b)	30 mm	Valenciennes
Etablissements Marit, Saint-Amand-les-Eaux (Nord).	U 1 (a) & U 1 (b)	44 mm	Valenciennes
Manufacture de Chaines et Ancres de Saint-Amand, Etablissements Sirot-Mestreit and Dorémieux Reunis. Saint-Amand-les-Eaux (Nord.)	U 1 (a), U 1 (b) & U 2 (a) U 1 (a), U 1 (b) & U 2 (a) (Etaifix)	100 mm 123,5 mm	Valenciennes Valenciennes
Soc. des Forges de Fresnes, Fresnes sur Escaut (Nord).	U 1 (a) & U 1 (b) U 2 (a)	65 mm 60 mm	Valenciennes
A. Veille et Cie., Le Havre.	U 1 (a), U 1 (b) & U 2 (a) U 1 (a), U 1 (b) & U 2 (a) (Monobloc)	100 mm 91 mm	Havre
Germany			
Dortmunder Kettenfabrik B. Mester, Dortmund.	U 1 (a) & U 2 (a)	69 mm	Dortmund
Joto-werk, Josef Topp Kettenfabrik, Warmen (Ruhr).	U 1 (a) & U 1 (b) U 2 (a)	68 mm 62 mm	Dortmund
Kettenfabrik Kalthof, August Thiele; August Thiele G.m.b.H. Fabrik für Ketten und Kettenforderer, Kalthof, near Schwerte-Ruhr.	U 1 (a), U 1 (b) & U 2 (a) U 3 (a)	105 mm 120 mm	Dortmund

Firm	Grade & Trade Name (if any)	Maximum Diameter	Surveying District
Germany—*continued*			
Kettenwerke Schlieper, Grune-Westfalen.	U 1 (a), U 1 (b) & U 2 (a)	110 mm	Dortmund
	U 3 (a)	120 mm	
Theile, J. D., Schwerte-Ruhr.	U 1 (a), U 1 (b) & U 2 (a)	92 mm	Dortmund
	U 3 (a)	56 mm	
Holland			
Anker-En Kettingfabriek "Schiedam", Schiedam.	U 2 (a)	78 mm	Rotterdam
Koninklijke Nederlandsche Grofsmederij, Leiden.	U 1 (a), U 1 (b) & U 2 (a) (Ego)	93.5 mm	Rotterdam
	U 1 (a) & U 1 (b) (Eldam)	75 mm	
	U 1 (a), U 1 (b) & U 2 (a)	105 mm	
India			
Indian Chain Manufacturing Co., Calcutta.	U 2 (a)	54 mm	Calcutta
Italy			
Acciaieria e Ferreira del Caleotto, Lecco.	U 1 (a), U 1 (b) & U 2 (a)	90 mm	Milan
Japan			
Hamanaka Chain Manufacturing Co. Ltd., Himeji.	U 1 (a), U 1 (b) & U 2 (a)	150 mm	Kobe
	U 3 (a)	155 mm	
Japan Mechanical Chain Manufacturing Co. Ltd., Osaka.	U 2 (a) (Kikai)	64 mm	Kobe
	U 1 (a), U 1 (b) & U 2 (a) (Flash welded)	58 mm	
Koyo Chain Mfg. Co. Ltd., Osaka.	U 1 (a), U 1 (b) & U 2 (a)	42 mm	Kobe
Osaka Chain & Machinery Mfg. Co. Ltd., Osaka	U 2 (a) & U 2 (b)	146 mm	Kobe
	U 3 (a) & U 3 (b)	127 mm	
Tokyo Chain & Anchor Co. Ltd., Tokyo.	U 1 (a), U 1 (b), U 2 (a) & U 2 (b)	150 mm	Yokohama
	U 3 (a)	120 mm	
Norway			
Norsk Kjettingindustri A/S, Mandal.	U 1 (a) (Short link)	25 mm	Oslo
	U 1 (a) (Stud link)	32 mm	
	U 2 (a) (Stud link)	27 mm	
Poland			
Stocznia im. Komuny Paryskiej, Gdansk.	U 1 (a), U 1 (b) & U 2 (a)	70 mm	Gdansk

Firm	Grade & Trade Name (if any)	Maximum Diameter	Surveying District
South Africa			
Cotts Steel Industries (Pty) Ltd., Johannesburg.	U 1 (a), U 1 (b) & U 2 (a)	$1\frac{1}{8}$ in	Vereeniging
McKinnon Chain (South Africa) (Pty) Ltd., Vereeniging.	U 1 (a) (Short link)	$\frac{3}{4}$ in	Vereeniging
	U 1 (a), U 1 (b) & U 2 (a)	2 in	
Spain			
Cadenas y Forjados, Bilbao.	U 1 (a), U 1 (b) & U 2 (a)	85 mm	Bilbao
	U 3 (a)	76 mm	
Don Ciriaco Rodriguez Dorado, Barcelona.	U 1 (a) & U 1 (b)	30 mm	Barcelona
	U 2 (a)	26 mm	
Vicinay S.A., Deusto.	U 1 (a) & U 1 (b)	95 mm	Bilbao
	U 2 (a)	114 mm	
	U 3 (a)	105 mm	
Sweden			
Gunnebo Bruks Aktiebolag, Gunnebobruk.	U 1 (a) & U 1 (b)	16 mm	Stockholm
Jarnbirger A/B, Orsa.	U 1 (a), U 1 (b) & U 2 (a)	55 mm	Stockholm
Ramnäs Bruks Aktiebolag, Ramnäs.	U 1 (a), U 1 (b) & U 2 (a)	98 mm	Stockholm
	U 3 (a)	92 mm	
Ström-Ljusne Aktiebolag, Kattingfabriken, Ljusne.	U 1 (a) & U 1 (b)	92 mm	Stockholm
	U 2 (a)	120 mm	
	U 3 (a)	120 mm	
United Arab Republic			
El Nasr Forgings, Cairo.	U 1 (a)	38 mm	Alexandria
United States of America			
Baldt Anchor Chain & Forge Division of Baldt Corp., Chester, Pennsylvania.	U 2 (a) (Weld in alternate links)	$\frac{5}{8}$ in	Philadelphia
	U 2 (a) (Flash welded)	$4\frac{1}{4}$ in	
Yugoslavia			
Tovarna Verig, Lesce.	U 1 (a), U 1 (b) & U 2 (a)	100 mm	Rijeka
	U 3	100 mm	

Chapter R

PROVISIONAL RULES AND GUIDANCE NOTES

Explanatory Notes

PROVISIONAL RULES give requirements which have been framed primarily for the initial regulation of ship and machinery applications in process of development ; they are subject to continuous review.

GUIDANCE NOTES are intended as recommendations to designers, based on good practice, in matters for which the present state of knowledge does not justify precise requirements.

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R (A)—PROVISIONAL RULES FOR THE USE OF METHANE GAS AS FUEL FOR THE PROPULSION OF METHANE TANKERS

Section 1

General

101 In methane tankers the methane "boil-off" may be used as fuel for propulsion services subject to compliance with the following Rules or equivalents; it is not to be used for firing auxiliary or domestic boilers or for auxiliary engine services.

102 These provisional Rules are based on the assumption that the pressure of the gas supply to the machinery space will not exceed 1 kg/cm² (15 lb/in²) gauge for boilers, and 7 kg/cm² (100 lb/in²) gauge for oil engines, and that the gas temperature in both cases will be approximately ambient. Where higher pressure or temperature conditions are proposed the arrangements will be specially considered.

It is also assumed that adequate oil fuel bunkers will always be carried and that the ship will not be entirely dependent on the methane "boil-off" for fuel requirements during any voyage.

Plans

103 The following plans are to be submitted for consideration:—

General arrangement of plant.

Gas piping system, together with details of interlocking and safety devices.

Gas heaters.

Gas compressors and their prime movers.

Gas storage pressure vessels.

Gas and oil fuel burning arrangements.

Equipment for Heating, Compressing and Storing Methane Gas

104 The methane gas is to be heated and compressed outside the machinery space. If the gas is stored in a pressure vessel the latter is also to be located outside the machinery space.

105 Gas heaters and compressors, of watertight construction, may be installed on the open deck provided they are suitably located and protected from mechanical damage. Alternatively, the heaters and compressors may be installed in a well ventilated compartment outside the machinery space. This compartment is to be treated as a dangerous space to which the requirements of M 16 for electrical equipment are applicable.

106 If steam is adopted as the heating medium the steam supply to the heaters is to be automatically controlled by the discharge temperature of the methane from the heaters, and the steam drains are to be led to a vented drain tank outside the machinery space. The vents are to be led to a safe position.

107 The prime movers for the gas compressors are to be regulated to maintain a positive suction pressure and arranged to stop automatically if the pressure on the suction side of the compressors is lower than 0,035 kg/cm^2 (0·5 lb/in^2) gauge or other approved positive pressure appropriate to the cargo tank system. They are also to be capable of being stopped, in emergency, from suitable positions on deck and in the machinery space.

108 Gas compressors of the piston type are to be fitted with relief valves discharging to a safe position. The relief valves are to be so proportioned and adjusted that the accumulation with the outlet valves closed will not exceed 10 per cent of the maximum working pressure.

109 The suction and discharge connections to the compressors are to be fitted with isolating valves and flame arresters.

110 Pressure vessels for storing methane gas are to be of approved design and fitted with pressure relief valves discharging to atmosphere in a safe position.

Ventilation of Machinery Spaces

111 Efficient arrangements are to be provided for the thorough ventilation of the machinery space under all climatic conditions and are to include a monitoring system with visual and audible warnings to detect gas leaks.

Gas Supply Pipes in Machinery Spaces

112 The gas supply lines in the machinery space are to be fitted in trunks or casings which are maintained by exhaust fans at a pressure slightly below that prevailing in the machinery space. The fans are to be of a type in which the electric motor is outside the ducting. The air discharge is to be led to a safe position and is to be monitored for methane leakage. Alternatively, the supply lines may be contained in trunks or casings pressurised by an inert gas at a pressure appreciably higher than the methane gas pressure. The gas supply lines are to be located remote from the ship's sides. Indicators of the trunk ventilation or pressurisation are to be provided.

113 The gas supply lines in the machinery space are to have all-welded joints so far as practicable, and are to be tested in place by hydraulic pressure to 7 kg/cm^2 (100 lb/in^2) or twice the working pressure, whichever is the greater. Subsequently, the lines are to be tested by air at the working pressure using "Soapy Water", or equivalent, to verify that all joints are absolutely tight.

114 Provision is to be made at a suitable position on deck for shutting off the gas supply before it enters the machinery space.

Purging Arrangements

115 Arrangements are to be made for purging the complete methane system with an inert gas or steam before and after pipes, auxiliaries, etc., are opened up for inspection or overhaul.

Electrical Equipment

116 The location of electrical equipment, including switchboard, is to be such that an accumulation of gas in the vicinity of such equipment is not possible.

MAIN BOILERS

Requirements for Burning Methane Gas

117 The boilers are to be equipped for oil firing in addition to the gas firing. Oil fuel alone is to be used for starting-up, manœuvring, and, except under clearly prescribed special conditions, for port operations.

118 Each boiler is to have a separate uptake to the top of the funnel or a separate funnel. The boiler room is to be separated from the engine room by a bulkhead, roller fire screen or equivalent. Special consideration will be given to proposals for combined engine and boiler rooms provided adequate ventilation arrangements ensure that any leakage of methane gas is extracted to atmosphere and other safety precautions are provided as required for each specific proposal.

119 The draught arrangements are to be such that a pressure differential is maintained between the boiler room and the combustion chamber either by induced

draught fans or by a closed stokehold system of forced draught. Alternatively, the boilers may be enclosed in a pressurised air casing.

120 The gas manifolds together with control valves are to be contained in a casing which is maintained below engine room pressure by an exhaust fan discharging to a safe position. Alternatively, the gas manifolds, valves, etc., may be contained in casings pressurised by inert gas as described in 112.

121 The firing equipment is to be of combined gas and oil type and be capable of burning both fuels simultaneously. The gas nozzles are to be so disposed as to obtain ignition from the oil flame which is to be present under all conditions of firing. A mechanical inter-locking device is to be provided to prevent the gas supply being opened until the oil and air controls are in the firing position. Each burner supply pipe is to be fitted with a gas shut-off cock and a flame arrester unless the latter is incorporated in the burner. An audible alarm is to be provided giving warning of loss of minimum effective pressure in the oil fuel discharge line or failure of the fuel pump.

122 Arrangements are to be made so that the gas supply to the gas manifold at each boiler can be shut off manually at the firing platform and will be shut off automatically as a result of failure of the forced draught fans or too low a pressure in the gas supply line.

123 In addition to the low water level fuel shut-off and alarm required by J 620 or J 635 for oil-fired boilers, similar arrangements are to be made for gas shut-off and alarm when the boilers are being gas-fired.

124 An inert gas or steam purging connection is to be provided on the burner side of the shut-off arrangements required by 122 so that the pipes to the gas nozzles can be purged immediately before and after methane gas is used for firing purposes.

125 A notice board is to be provided at the firing platform stating:—

> If ignition is lost from both oil and gas burners, the combustion spaces are to be thoroughly purged of all combustible gases before re-lighting the oil burners.

MAIN OIL ENGINES

Requirements for Using Methane Gas

126 Main engines are to be of the dual fuel type employing pilot oil fuel ignition and capable of immediate change-over to oil fuel only. All starting and manœuvring is to be carried out on oil fuel alone.

127 The gas is to be admitted to each cylinder via a separate gas inlet valve; i.e. a system whereby gas is supplied to and mixed with air in a common inlet manifold is not acceptable from safety considerations. The gas supply pipes to individual cylinders are to be fitted with shut-off valves, non-return valves and flame arresters.

128 Isolating valves are to be provided at the inlet to the gas supply manifold for the engine and are to be arranged to close automatically in the event of low gas pressure and failure of pilot fuel injection. Arrangements are to be made so that the gas supply to the engine can be shut off manually from the starting platform.

129 Explosion relief valves are to be provided in the exhaust, scavenge and air inlet manifolds for conditions where, for example, a cylinder misfires due to failure of the pilot fuel injection or other derangement.

130 A cowl or casing connected to an exhaust ventilator is to be fitted over the cylinder tops so that gas leakages may be intercepted and led to a safe position. No electrical equipment is to be fitted inside these cowls and casings.

131 If a trunk piston engine is used the crankcase is to be fitted with smoke detecting equipment and means for the automatic injection of inert gas to avoid the special hazard of an explosion in a crank case which normally will contain a methane/air mixture. Crank case relief valves are also to be fitted as required by H 6.

Survey

132 The gas compressors, heaters, pressure vessels and piping are to be constructed under Special Survey, and the installation of the whole plant on board the ship is to be carried out under the supervision of the Society's Surveyors.

23rd July, 1970

R (B)—PROVISIONAL RULES FOR PLASTIC PIPES

Section 1

101 Proposals to use plastic type materials in shipboard piping systems will be considered in relation to the properties of the materials, the operating conditions of temperature and pressure, and the intended service.

The Rules which follow are intended for extruded plastic pipes; they may also be used, where applicable, for fabricated plastic pipes glass reinforced. Any proposed service for plastic pipes not mentioned in these Rules is to be submitted for special consideration.

102 A specification of the plastic material giving mechanical and thermal properties is to be submitted for consideration.

103 In general, plastic pipes are not to be used where they will be subjected to temperatures above 49°C (120°F) or below 0°C (32°F).

104 Plastic pipes of approved type may be used for the following services:—

(*a*) Air and sounding pipes to tanks used exclusively for carrying water ballast or fresh water, with the exception of the portion above deck.

(*b*) Sounding pipes to cargo holds.

(*c*) Water ballast and fresh water pipes situated inside tanks used exclusively for carrying water ballast or fresh water.

(*d*) Scupper pipes draining inboard provided they are not led within the boundaries of refrigerated chambers.

Items (*a*) and (*b*) are not applicable to passenger ships.

105 Plastic pipes may be used for domestic and similar services for which there are no Rule requirements, as follows:—

Domestic cold salt and fresh water systems.

Sanitary salt water systems.

Sanitary and domestic waste pipes wholly situated above the freeboard deck.

Water pipes associated with air conditioning plants.

106 Since plastic materials are generally heat sensitive and very susceptible to fire damage, plastic pipes will not be acceptable for services essential to safety, as follows:—

Fire extinguishing pipes.

Bilge pipes in cargo holds.

Bilge and ballast pipes in the machinery space.

Main and auxiliary water circulating pipes.

Feed and condensate pipes.

Pipes carrying oil or other flammable liquids.

107 If plastic pipes are arranged to pass through watertight or fire-resisting bulkheads or decks provision is to be made for maintaining the integrity of the bulkhead or deck in the event of pipe failure. Details of the arrangements are to be submitted for approval.

108 Pipes are to be of robust construction, and in general so designed that the wall stress will not exceed $\frac{1}{7}$ of the tensile strength of the material at the working temperature. Particulars of scantlings and joints are to be submitted for consideration.

109 All pipes are to be adequately but freely supported; suitable provision for expansion and contraction is to be made in each range of pipes to allow for large movements between plastic pipe and steel structure—the coefficient of thermal expansion for plastics being eight or more times that of steel.

110 All fittings and branches are to be suitable for the intended service having joints of cemented, flanged, or other approved type.

111 The strength of the plastic material is to be check tested at the Surveyor's discretion. The tensile strength is to be determined by pressure tests to destruction on sample pipes. The pressure is to be so applied that failure of the pipe occurs in not less than five minutes. Bulging of the pipe during test is acceptable. The tensile strength is to be taken as the hoop stress at failure based on the original pipe dimensions.

28th February, 1963

R (C)—PROVISIONAL RULES FOR THE CLASSIFICATION OF NUCLEAR SHIPS

Section 1

GENERAL

101 The class notation "Nuclear Powered" will be assigned, in accordance with the provisions of Chapter B, to sea-going ships equipped with a nuclear reactor or reactors for main propulsion and built in accordance with, or equivalent to, the relevant Rules and the following special requirements.

102 The requirements of Chapters C to Q apply as may be relevant to nuclear-powered ships, except as otherwise required by the following Rules.

HULL

Definitions

103 The containment structure is the vessel or ship compartment containing the reactor, primary circuit and associated equipment.

104 The containment protection length is the overall length of the containment structure plus a marginal length at each end. The marginal length is to be not less than B/5 with a minimum of 3 m (10 ft).

105 The reactor compartment is that compartment of the ship containing the containment structure. Where the containment structure is integral with the hull the reactor compartment is the containment structure (*see* 103).

Method of Construction

106 Welded construction is to be adopted for all structural material bounding the containment structure.

Quality of Material

107 The material of deck, sheerstrake, side and bottom shell plating, including keel, over the containment protection length is to be of Grade E.

Longitudinal Strength

108 Curves of weight and buoyancy in still water, and the corresponding bending moments and shear forces are to be submitted. The minimum section modulus for the hull shall be in accordance with the requirements of the Rules. In general, the arrangements and loading should be so adjusted that the maximum stress in still water does not exceed 90 per cent of the normal Rule maximum.

109 The longitudinal extent of the midship thicknesses of the deck, sheerstrake, side and bottom shell plating will be considered in association with the bending moment and shear force diagrams, but is to be not less than required by the appropriate section of the relevant Rules.

110 Continuity of longitudinal strength members is to be provided and rapid changes of section are to be avoided. The containment protection may be tapered to the normal structure over the marginal length.

111 Rigid shielding must not encase hull structural members unless built up in units with overlapping or socketed joints to permit free deflection of the ship girder. Thick steel or sandwich structures should not be made an integral part of the hull structure for similar reasons.

External Shock

112 The support system for the reactor and associated components should be designed to withstand a shock or impact acceleration of 3 g in any direction without general deformation of the structure.

Collision and Grounding Protection

113 No part of the containment is to extend outside a vertical datum B/5 metres (feet) inboard of the ship's side at the load water line.

114 The structure of the ship below the reactor and at the sides in way of the containment protection length will require to be specially considered from the aspect of absorption of the energy of collision and grounding forces.

115 Details of the side shell framing and collision protection structure in way of the containment protection length are to be submitted for approval.

116 A double bottom structure of depth not less than 1,85 m (6 ft) is to be fitted in way of the reactor and should incorporate a system of longitudinal framing in association with bottom transverses.

117 The integration of the containment with the hull structure should be such that the bottom shell in way of

the reactor should be capable of sustaining comparatively severe local damage without prejudicing the support of the reactor and its relative position in the ship.

118 A watertight longitudinal bulkhead is to be fitted between the reactor and the ship's side, not less than 1,5 m (5 ft) from the inner line of primary shell supporting members (or inner skin if double skin construction is adopted) at the load water line. The minimum clearance between this bulkhead and the reactor installation will be considered in association with the form of collision protection adopted. This bulkhead should, wherever possible, be in line with similar longitudinal material in the half length amidships. Where this is not possible, the arrangements for continuity are to be specially approved.

119 Proposals for the carriage of liquids, or siting of auxiliary machinery, abreast the reactor installation will be the subject of special approval.

Cargo Hazard Protection

120 Cargo spaces are to be isolated from the reactor compartment by a cofferdam not less than 1,5 m (5 ft) in length. For this purpose the machinery spaces and pump rooms will be regarded as equivalent to cofferdams. The modulus of the stiffening members of the cofferdam bulkhead adjacent to the reactor compartment is to be twice that required by D 50.

Containment Structure

121 Where containment is provided by a pressure vessel independent of the ship's structure, R (C) 216 to 225 apply.

122 The arrangements of such a containment structure are to be such that the transmission of stresses from the hull structure is reduced to a minimum.

123 Where the maximum major accident pressure (*see* R (C) 501) does not exceed 2 kg/cm^2 (30 lb/in^2) gauge the containment may be provided by a compartment of the hull structure. All material of such containment structures is to have impact properties as specified for Grade E. Details of the proposed material are to be submitted.

124 The design stress for hull containment structures must not exceed two thirds of the yield stress or one third of the ultimate stress under the major accident conditions (*see* R (C) 501). Temperature effects will be specially considered. The structure should also be capable of withstanding an external pressure of 3,5 kg/cm^2 (50 lb/in^2) gauge.

125 Containment structures are to be tested on completion in accordance with R (C) 224 and R (C) 225.

Section 2

PRESSURE VESSELS AND COMPONENTS

201 Pressure vessels and components for nuclear installations are to be considered in the following categories:—

Category "A"

Pressure vessels and components which are:—

1. Intended to contain radioactive materials in service,

and

2. Either (i) subject to direct neutron irradiation such that the physical properties of the materials of construction will be significantly affected during the projected life of the nuclear installation, or (ii) inaccessible for normal comprehensive periodic examination and maintenance from biological considerations of radioactivity.

Category "B"

Pressure vessels and components which are:—

1. Intended to contain radioactive materials in service,

and

2. May be subject to direct neutron irradiation but not such that the physical properties of the materials of construction will be significantly affected during the projected life of the nuclear installation, but which will be accessible for normal comprehensive examination and maintenance at any selected time during the projected life of the nuclear installation.

Category "C"

Pressure vessels and components which are:—

1. Not intended to contain radioactive materials in service.
2. May be subject to direct neutron irradiation but not such that the physical properties of the materials of construction will be significantly affected during the projected life of the nuclear installation and which will be accessible for normal comprehensive examination and maintenance at any selected time during the projected life of the nuclear installation.

Containment

Containment structures are defined in R (C) 103.

Category "A"

202 The materials of construction of these vessels are to be of a readily weldable quality, of adequate corrosion resistance and chosen from types which have been proven in pressure vessel service under similar conditions for non-nuclear applications. Data relating to the probable behaviour of materials under irradiation should be available.

203 Irradiation monitoring specimens representative of the materials of construction and of the welding of the vessels are to be provided. A programme of monitor specimen testing is to be drawn up covering the projected life of the nuclear installation.

204 Pressure vessels are to be designed and constructed generally in accordance with the Rules for Welded Pressure Vessels, Class 1. Alternatively, they may be designed generally in accordance with B.S. 1500 Class 1 or an approved code of a recognised National Authority.

The design conditions to be adopted are as follows:—

Design pressure is to be the maximum pressure under normal continuous and transient operation. Additionally, the relief valves must ensure that under emergency conditions the accumulation pressure must not exceed 1,10 × design pressure.

Design temperature to be the maximum coolant temperature under normal operating conditions.

205 The effect of the following factors on stress levels must also be taken into consideration:—

(a) (i) Internal and external loading applied by or through circuits, supports and other connections, and self weight.

(ii) Temperature differentials and gradients occurring during normal operation, including start-up and shut-down.

(b) Shock and impact loading (*see* R (C) 112 and R (C) 521).

206 Special attention is to be given to effecting a clean design minimising stress concentrations. Reinforcement of major nozzle and other openings in the main pressure shell by the use of doubling plates is not permitted. Weldments are to be designed to permit 100 per cent radiography wherever possible.

207 The weld procedure specification is to be prepared giving details of the proposed methods of fabrication, including all pertinent welding variables and proposed methods of non-destructive examination. The specification must also include proposals in respect of the following:—

(a) Weld procedure tests to prove the proposed methods.

(b) Welding operator tests to prove each welder's ability.

(c) Production tests to prove the maintenance during fabrication of the standard of welding established and approved under weld procedure tests. Such tests are to be representative of the final conditions of the welding of the completed vessels and components.

The above tests are to be carried out under the conditions obtaining during fabrication.

208 On completion of fabrication, a hydraulic test is to be applied to a pressure 50 per cent in excess of the design pressure corrected for any increase in thickness incorporated as a corrosion allowance and for any difference in the physical properties of the vessel materials between test and design temperatures.

Category "B"

209 The requirements for vessels in this category are as for Category "A", except that irradiation data on materials is not required.

Internal and external access for normal comprehensive periodic examination of all vessels and components which are accessible from biological considerations of radioactivity is to be provided.

210 The pressure tightness of fuel assembly containers and associated coolant systems should also be considered in this category. Where closure of the pressure shell is effected by mechanical means, facilities are to be provided to test the integrity of the joint against leakage at any selected time.

Categories "A" and "B"

211 Vessels and components of the primary circuit are to be shop fabricated and shop tested wherever possible. The number of *in situ* closing welds must be kept to a minimum and adequate access is to be provided in each case.

212 On completion of the installation of the primary circuit a test pressure of 1,5 × design pressure is to be applied.

A leak test is also to be applied to the completed primary circuit for each proposed installation in a manner approved by the Society.

213 Provisions are to be made to facilitate periodic pressure and leak testing of the primary circuit.

214 Construction of these vessels is to be carried out in such a way that the high standard of cleanliness required can be attained.

Category "C"

215 Vessels in this category are to be designed, constructed and tested in accordance with the Rules for Welded Pressure Vessels (Chapter J) or other approved code or specification.

Containment

216 Materials for the construction of these structures are to be of a readily weldable quality and chosen from types which have been proven in service.

217 Where part of the ship structure is used as containment, R (C) 123 to 125 are applicable.

218 Pressure vessels are to be designed and constructed generally in accordance with the Rules for Welded Pressure Vessels, Class 1. Alternatively, they may be designed in accordance with B.S. 1500 Class 1 or an approved code of a recognised international authority. The allowable design stress must not exceed the lesser of the following:—

Two thirds of yield stress (or two thirds of the 0,2 per cent proof stress),

One third of ultimate tensile stress.

219 No means of internal pressure relief are to be fitted. The design conditions to be adopted are as follows:—

Design pressure (internal) is normally to be the major accident pressure in kg/cm^2 (lb/in^2) gauge. (*see* R (C) 501).

Collapse pressure (external) is to be not less than 3,5 kg/cm^2 (50 lb/in^2). Arrangements to protect the vessel when subjected to pressure in excess of the collapse pressure should be submitted for approval.

Temperature effects are to be considered (*see* R (C) 502).

220 The following factors are also to be taken into consideration:—

(a) Internal and external loading applied from ship's motion, machinery installation and shielding.

(b) Shock and impact loading (*see* R (C) 112 and R (C) 521).

221 Where it is envisaged that items of equipment within the containment will be removed or replaced during the life of the installation, adequate shipping openings with mechanical closures are to be provided to avoid recourse to cutting the containment structure in service.

222 The number and size of all openings in the pressure shell is to be kept to a minimum.

Isolating valves must be provided for all pipe circuits penetrating the pressure shell and these are to be situated in accessible locations outside, and adjacent to it. These valves are to be power operated or otherwise arranged to ensure rapid closure when containment is invoked.

223 A weld procedure specification is to be provided.

224 On completion of fabrication an internal hydraulic test to a pressure of at least 25 per cent in excess of the design pressure is to be applied.

225 A leak test to enable the determination of leakage rates from the containment structure at design pressure is to be conducted. Leakage from the containment structure should be kept to a practical minimum. The target figure to be adopted is 1 per cent in 24 hours of the free volume of the gaseous content in the containment vessel with all machinery installed.

Pressure Control and Over-pressure Relief

226 For each pressure vessel in the primary and secondary circuits in which it is possible under any foreseeable conditions for the pressure to rise above the maximum design pressure, over-pressure relief must be possible.

227 The design requirements for primary and secondary pressure control systems are to include an agreed failure of the primary/secondary boundary. The effect of the consequent transfer of fluid from the primary to the secondary circuit or from the secondary to the primary circuit is to be assessed.

Discharge from primary pressure circuits is to be contained (*see* R (C) 513).

228 In systems where it is practicable to provide total relief capacity during any emergency condition by fitting one safety valve only, an additional safety valve of equivalent capacity is to be fitted. In multi-valve systems, additional safety valves are to be fitted in excess of the number required to provide total relief capacity. The number of additional valves to be provided will depend on the operational reliability of the safety valve types and the number involved.

Relief systems are to be designed to provide total relief capacity during any emergency condition with the maximum pressure accumulation of 10 per cent of the design pressure with the additional safety valves isolated.

229 Provision is to be made to detect leakage from each safety valve in normal operation. Provision is to be made to effect isolation of each safety valve during reactor and circuit operation. The shut-off arrangements are to be interlocked to ensure that the number of valves required to effect total relief are on line.

230 A pressure connection is to be provided to enable testing of safety valve lift *in situ*.

If block valves are proposed in safety valve discharge lines, a low pressure bursting disc must be incorporated in the valve design.

231 Proposed departures from the above requirements will be given special consideration.

Section 3

REACTOR ENGINEERING

General Requirements

301 Normal reactor and main machinery control during power operation are to be effected from a central control position external to the reactor compartment. An emergency reactor shut-down position with monitoring instrumentation is to be provided remote from the central control position.

302 Where isolation of the primary flow between reactor and heat exchanger is not provided, means of individual remote isolation of the secondary side of the heat exchangers is to be provided adjacent to the heat exchangers.

303 Individual isolation of the primary coolant subsidiary circuits is to be provided.

304 Data on the expected degree of irradiation effect to moderator and coolant is to be provided and the proposed method of monitoring and controlling such effect throughout ship life is to be stated.

305 Materials of construction which come into contact with primary fluid should be examined in relation to the build up of corrosion products activity within the reactor system. Details of proposed coolant treatment facilities are to be supplied.

306 Data and, if possible, experimental evidence relating to the power stability of the reactor under regular cyclic motions up to accelerations of 0,45 g as may be obtained in a seaway are to be provided. As a design criterion a period of 12 seconds should be used regardless of size and type of ship or position of reactor.

307 Special consideration is to be given to the fire resistance of all materials used in the containment structure and reactor compartment having regard to normal operating conditions and defuelling. Fire protection facilities provided in the containment structure and the reactor compartment are to be submitted for approval.

308 The provision and location of all spare equipment for nuclear components is to be detailed.

309 At least two independent means of charging coolant into the primary system are to be provided.

Reactor Core

310 A specification of all materials proposed for use in the core structure is to be submitted for approval.

311 The data and calculations utilised in the core design are to be submitted for approval.

Where necessary, adequate safeguards must be provided to prevent any dangerous chemical reaction between reactor materials and air or water.

312 The mechanical design, dimensional integrity and manufacturing tolerances of the core structure are to be submitted for examination and approval. Where applicable, the possible relative movement between neutron absorber control material and the core is to be assessed.

313 All possible normal and abnormal reactor transients are to be evaluated and their effect upon the dimensional stability and strength of the reactor core support structure is to be assessed.

314 It is recommended that all reactor pressure vessel internals are to be capable of being dismantled and removed from the pressure vessel. Proposals are to be submitted for consideration.

315 The core structure and fuel assembly are to be capable of withstanding shock and impact loading (*see* R (C) 112 and R (C) 521).

316 The expected change of the physical and chemical properties of the materials proposed for use in the fuel assembly, with irradiation, are to be submitted for approval.

317 The design of the fuel assembly and the operating criteria upon which the design is based are to be submitted for examination. All possible transient conditions (*see* 313) must be examined and related to possible fuel element failure. Experimental evidence of the mechanical strength of the fuel assembly resulting from transient conditions should be provided where possible.

318 The concentration and composition of fission products in the fuel at the end of the designed core life are to be assessed assuming a final period of 100 hours full-power operation.

319 The evidence upon which the fuel element dimensional stability has been assessed including, where possible,

previous reactor experience with the proposed fuel assembly up to the full proposed design irradiation is to be submitted for examination.

320 The consequences of salt water contamination of the primary coolant and the corrosion rates of the fuel assembly materials in coolant and in sea water are to be determined.

321 An analysis of the consequences of complete loss of coolant flow with and without control action is to be provided.

322 An analysis of the consequences of staggered loss of coolant flow with and without control action is to be provided.

323 An analysis of possible events leading to and resulting from the sudden introduction of cold coolant into the reactor core is to be provided.

324 The influence of random variations in moderator composition is to be examined.

325 An analysis of the consequences of a restriction of coolant flow in a fuel assembly is to be provided.

326 Each main coolant circuit must be provided with an independent means of circulating coolant. A single loop reactor system must be provided with a minimum of two main coolant circulators. It is recommended that a spare pump unit be carried.

327 Alternatively, if natural convection is proposed as a sole means for primary coolant circulation, proposals are to be submitted for consideration.

328 An analysis of the consequences of leakage of primary coolant and associated loss of pressure with and without control action is to be provided.

Decay Heat Removal

329 The arrangements to remove decay heat from the core under normal shut-down conditions are to be submitted for approval. Data, together with method of calculation, is to be provided showing the assessment of variation of decay heat with time.

330 Where a single loop circuit is proposed, a decay heat removal system independent of the main coolant loop is to be provided.

331 Facilities, independent of normal electrical power supplies, are to be provided to remove decay heat from the core at angles of list up to 50°.

It should be assumed that the ship lists to 20° instantaneously and that the list continues to increase at the rate of 20° per hour.

Section 4

REACTOR CONTROL

General Requirements

401 The proposed procedures for start-up and normal and emergency plant operation are to be submitted for approval.

402 The design of the control arrangements and any associated mechanism and the power supply to such mechanisms are to be submitted for approval. Evidence of operational reliability and proposed cycling tests to prove reliability are to be indicated.

403 The physical and chemical properties of materials used in control rod and associated mechanisms are to be submitted for approval. Corrosion rates of control equipment in reactor environment and in sea water are to be determined.

404 The control arrangements are not to move out of the core under gravity, under the force of coolant flow, shock loads or ship movement.

405 A degree of operator adjustment of the control arrangements is to be possible. Protection against possible operator error is to be provided.

406 The normal full-power operating temperatures of control rods are to be determined and the maximum temperature obtaining with one rod stuck in the core is to be determined, together with consequential effects.

407 The maximum insertion and withdrawal rate of any form of control is to be stated and related to possible reactor instability.

408 The consequences of continuous control rod withdrawal at start-up and full power are to be calculated.

409 The control equipment and its associated mechanisms when supported in their environment are to be capable of withstanding shock and impact loading (*see* R (C) 112 and R (C) 521).

410 The control arrangements are to be capable of operation at all ship angles and in the event of power failure must fail safe.

411 A margin of control should be completely withdrawn prior to criticality. The reduction of reactivity effected due to insertion of this margin at full power, at start-up and at all stages of core lifetime should be stated.

412 An alternative method of shutting down the reactor which is not affected by structural distortion of the core is to be provided, e.g., dumping of the moderator or change in moderator mixture or added poison. The time required to operate the system is to be stated.

Calculations or experiments supporting the design of the chosen system should be submitted for appraisal.

413 The plant parameters and the analysis of transient conditions under which emergency shut-down will be initiated are to be submitted for appraisal.

414 Emergency shut-down of the reactor must be implemented at the following ship conditions:—

(i) 50° list.

(ii) Flooding of the containment.

415 The method proposed to pressurise the primary circuit is to be submitted for approval.

Instrumentation

416 Control instrumentation and supplies are to be defined so as to meet control requirements and fault conditions. The instrument response to reactor transients is to be demonstrated.

417 All nuclear instrumentation, including health physics monitoring equipment, is to be described and its accuracy, reliability and range of operation demonstrated.

418 The method and extent of duplication of essential nuclear instrumentation and supplies is to be stated.

It is required that failure of any item of equipment in any channel shall result in a non-safe indication from that channel. Provision to test each channel without loss of reactor protection is to be possible.

419 All instrumentation relating to the reactor and the reactor compartment is to be described and the range of operation demonstrated.

420 Basic reactor safety instrumentation at the central control position and at the emergency shut-down position must be adequately shock mounted to ensure accuracy and reliability (*see* R (C) 112 and R (C) 521).

Section 5

COMPLEMENTARY INSTALLATION REQUIREMENTS

Major Accident

501 A containment vessel or structure is required that encloses all primary coolant circuits and the design of this is to be related to a pressure resulting from a major accident. This accident should be based on an appreciation of the particular reactor design and is to include:—

(a) Examination of possible nuclear transients contributing to the energy content of the primary circuit.

(b) Assumption of complete severance of a main coolant pipe or equivalent failure occurring at working pressure and resulting in discharge of primary coolant into the containment.

(c) Assumption that failure of the secondary circuit discharges a proportion of the secondary fluid into the containment.

(d) Consequent exothermic chemical reaction which might result from core melt-down.

502 A pressure/time curve and temperature/time curve of the containment vessel contents covering the first 24 hours after the accident are to be submitted for examination, together with relevant calculations. In addition, the provision to prevent molten fuel penetrating the containment is to be indicated. Where "vapour suppression" or other such means of attenuation of the pressure rise following an accident are proposed full details are to be submitted at an early stage in the design, together with evidence of their effectiveness.

503 An assessment is to be made of possible damage to the containment structure by missiles produced as a consequence of a component failure inside the containment.

504 A summary of credible accidents covering each particular installation and indicating the degree of hazard involved is to be submitted for consideration. This summary must include a schedule of containment penetrations detailing methods of closure.

Shielding

505 Radiation contours in and around the hull, together with method of determination, are to be submitted for approval. Such contours should be determined for full-power operation, shut-down, dry docking, defuelling and after the major accident which invokes the use of containment.

506 In general, designers should work to the recommendations of the International Commission of Radiological Protection so that crews do not receive an integrated radiation dose in excess of 5 rem per year. When the integrated dose is calculated the possible need for maintenance work in high irradiation areas must be considered and it is recommended that 40 per cent of the total dose be reserved for this purpose.

507 The design of primary and secondary shielding, together with their siting and method of securing in the hull structure, are to be submitted for approval. Where necessary, arrangements for shield cooling and ventilation are to be indicated. Adequate periodic examination of the parent structure must be possible.

Defuelling and Refuelling

508 The arrangements for reactor shut-down for maintenance purposes and immediately prior to defuelling are to be submitted for approval.

509 Removal of a fuel assembly from the core into a container is to take place in such a manner that there will be no hazardous release of fission products to environment. The reactor core is to be in a containment of agreed design at all times. In addition, irradiation hazards to personnel are to be limited and should not exceed the maximum dose rates as recommended by the International Commission of Radiological Protection.

510 The fuel container is to be capable of being cooled and the consequences of failure of cooling are to be examined. The method of cooling and any related design of coolant circuit are to be submitted for approval.

511 The design of fuel containers is to be related to an approved maximum pressure and temperature to which they may be subjected, and the leak rate of the containers under such conditions is not to exceed 0,1 per cent per 24 hours of the gaseous volume of the container loaded with a fuel assembly.

Effluent Disposal

512 The facilities provided on board for the storage of radioactive material obtained from the reactor systems and the method proposed for the removal and the subsequent storage ashore is to be submitted for approval.

513 In general, containment of all solid and liquid effluents is required and the design of equipment used to effect such containment for a period of three months full-power operation and to permit its controlled discharge is to be submitted for approval.

Temporary storage and controlled discharge of innocuous concentrations of gaseous effluent is acceptable, subject to meeting national and international requirements.

Adequate monitoring devices for solid, liquid and gaseous effluent must be provided in all instances.

514 The designs and proposed method of operation of air circulating, air conditioning or air purging equipment in the containment structure are to be submitted for approval. The capacity of the equipment is to be related to the net volumes of the compartment and is to permit complete processing of such volumes in 30 minutes. All air before discharge is to be passed through a fission product clean-up unit.

Electrical Installations

515 Electrical installations are to be in accordance with Chapter M and, in addition, with the following Rules.

516 Limits of voltage and/or frequency between which equipment will operate satisfactorily are to be stated.

517 The electrical installation is to be such that failure of any component (e.g., generators, motors, busbars, protective devices or cables) does not interrupt the supply to services essential for the safety of the ship.

518 Emergency supplies in the event of reactor shut-down and/or failure of main supplies must be stated.

Secondary Circuit

519 Secondary circuit equipment and machinery, other than primary and secondary heat exchangers, are to conform with the Society's Rule requirements. Power must be available to permit normal manœuvring of the ship and the flexibility of the system is to be shown to accommodate all variations in main engine demand.

The reactor transients under such conditions are to be submitted for examination.

Emergency Power

520 Unless two or more reactors capable of independent operation are fitted, an independent power supply separate from and independent of the nuclear machinery must be available. The power output of such machinery must maintain a ship's speed of not less than six knots.

A range of 1600 kilometres (1000 miles) is recommended.

Shock

521 All reactor components are to be capable of withstanding an impact or shock acceleration of 3 g acting for a perceptible period of time in any direction using the yield stress or proof stress of the materials as a strength criterion.

Cleanliness

522 A high standard of cleanliness is to be maintained during construction of reactor components and their assembly into a hull. The methods and techniques required to obtain such a standard are to be submitted for approval.

Section 6

SURVEY AND MAINTENANCE

601 All proposed procedures for servicing and maintenance are to be included in the Operations Manual which is to be submitted for examination.

602 Hull and main machinery shall be subject to normal survey requirements.

603 All machinery used directly in conjunction with the reactor shall normally be subject to survey at four-yearly intervals, or at each refuelling period, whichever is the shorter.

604 The survey requirements for Category "A" pressure vessels and components will be given special consideration for each installation proposed.

605 The main steam generators and associated components in the containment which fall in Categories "B" and "C" (*see* R (C) 201), together with supports and seatings, shall be subject to survey at four-yearly intervals or at each refuelling period, whichever is the shorter.

606 Containment structures and supports are to be subject to survey at four-yearly intervals and a leak test is to be carried out at that time or in the event of minor modification or repairs to the pressure envelope. The leak test is to be carried out at 50 per cent of the major accident pressure, or at a lower agreed figure provided a leak rate/pressure curve has been determined.

607 An air test to the design pressure is to be carried out on a containment structure whenever a major modification or repair to the pressure envelope is made, or when significant deterioration of the envelope is noted.

608 Double bottom structure external to and in way of the containment vessel shall be subject to survey at four-yearly intervals or at each refuelling period, whichever is the shorter.

609 Primary and secondary shielding, together with associated parent structure, shall be subject to survey at four-yearly intervals or at each refuelling period, whichever is the shorter.

610 The design of the reactor installation should permit maintenance work, servicing and inspection to be carried out without excessive exposure of personnel to radiation hazards, which should not exceed permissible dose rates as laid down by the International Commission of Radiological Protection.

611 Containers for radioactive material are to be subject to examination by the Society's Surveyors at two-yearly intervals except that, where chemical decontamination is used or other severe conditions obtain, it may be required that more frequent examinations be effected.

29th April, 1965

R (D)—GUIDANCE NOTES ON METAL PIPES FOR WATER SERVICES

Section 1

PIPES FOR SEA WATER SERVICES

Types of Corrosion

101 The following types of accelerated corrosion have arisen with piping materials for sea water services:—

(a) Galvanic corrosion of the less noble metal where dissimilar metals were in association.

(b) Pitting corrosion, the main causes being local attack by deposits or transfer of small pieces of metal such as weld spatter, sulphides in polluted esturine waters, gassing in hot tubes of coolers, fouling and cathodic films in the bores of pipes as a result of incorrect methods of manufacture or fabrication.

(c) Corrosion-erosion where water speeds are excessive for particular metals. This may be particularly severe where turbulence occurs, e.g., protrusions in pipe bores, tight bends.

(d) Dezincification of some types of brasses including "manganese bronze".

(e) Stress corrosion cracking of copper-zinc alloys.

(f) Severe local corrosion due to sulphur and/or sulphide contamination of pipes.

(g) Cavitation erosion where water speeds are very high.

(h) Rusting of steel pipes when no protection has been applied or where protection has proved insufficient due to manufacturing fault or damage.

102 Metals differ in their resistance to these various forms of corrosion but even where corrosion resistant types have been used, inadequate attention to design detail or workmanship has caused failures. The following are recommendations for the selection of materials and practices.

Materials for Pipes and Flanges

103 Steel pipes should be protected against corrosion. Galvanising of the bores is the most common practice and is recommended as the minimum protection. All steel pipes of bilge and ballast lines should be galvanised.

Galvanised steel pipes should not be used for continuous service where water speeds exceed about 3 m/second (10 ft/second).

The life of a galvanised coating depends on its thickness which to some degree is controlled by pipe thickness. In some cases, it may be advisable to use a pipe of heavier gauge. Welds should be free from lack of fusion and crevices. Where possible, the surfaces should be dressed to remove slag and spatter and, where possible, this should be done before galvanising. Preferably the coating should be continuous round the ends of the pipes and on the faces of flanges.

104 Rubber-lined steel pipes can give excellent service. The lining is resistant to all forms of corrosion and is particularly effective against scouring by sand. A good bond between the rubber lining and the steel of the pipe is essential. Preferably the rubber lining should be carried round the ends of the pipe and over the faces of the flanges to act as jointing material. There should be no discontinuities or pinholes in the lining, through which corrosion can occur and lift the coating. For these reasons rubber linings should be applied by specialist firms and care taken to avoid damage to finished coatings.

The foregoing comments also apply to plastic-lined pipes. Pipes with stoved coatings are also efficient, but care should be taken to avoid mechanical damage to flanges.

Coatings of the above types should be applied on completion of fabrication, i.e., forming and welding of steel pipes.

105 Copper pipes are particularly susceptible to perforation by corrosion-erosion. These pipes have given the greatest trouble in sea water systems. In some cases copper pipes have been replaced by galvanised steel pipes which have given superior performance.

The cause of the failures of copper pipes has been due mainly to the continuation of an established practice over a period when water speeds have increased appreciably. Low water speeds should be used with copper pipes and excessive local turbulence should be avoided.

106 Certain copper alloys have enhanced resistance to impingement attack and can be used where water speeds are higher than can be tolerated by copper. These alloys are as follows:—

Copper—30 per cent Nickel—0·8 per cent Iron Alloy.
Copper—10 per cent Nickel—2 per cent Iron Alloy.
Aluminium Brass.
Admiralty Brass.
Copper—5 per cent Nickel—Iron Alloy.

In general, aluminium brass pipes and tubes give reliable service with reasonably clean sea water. For service with polluted river or harbour waters copper-nickel-iron alloy pipes and tubes are preferable. The nickel content of the alloy for these conditions should not be less than 10 per cent. New copper alloy pipes should not be exposed initially to polluted water. Reasonably clean sea water should be used first in order that the metals can develop protective surface films.

107 Austenitic types of stainless steel are not recommended as they are prone to deterioration when in contact with polluted waters.

108 Where pipes are exposed to sea water on both external and internal surfaces, flanges should be made preferably of the same material. When sea water is confined to the bores of pipes the material of the flange is of less importance from the point of view of corrosion. However, flanges of the same or a less noble metal than that of the pipe, are recommended. Gunmetal flanges on aluminium brass pipes are an exception to this recommendation. Brass for flanges should be of the type containing 1,0 to 2,0 per cent tin to minimise dezincification.

109 Fixed or loose type flanges may be used. The fixed flanges should be attached to the pipes by fillet welds or capillary silver-brazed joints as appropriate. Where welding is used, the fillet weld at the back should be a strength weld and that in the face a seal weld.

Where silver-brazing is used, strength should be obtained by means of the bond in a capillary space over the whole area of the mating surfaces. A fillet braze at the back of the flange or at the face is undesirable.

A combination of a silver-brazed joint at the front face and a normal brazed joint at the back face has given satisfactory service when the bore surface only was exposed to sea water.

110 With copper-nickel-iron alloy pipes, flanges of a similar type of alloy or of mild steel may be attached by argon arc welding. A mild steel flange should not be used when it will be in contact with sea water.

Copper, brass, bronze, gunmetal or copper-nickel-iron alloy flanges may be capillary silver-brazed to copper, aluminium brass or copper-nickel alloy pipes. "Bronze welding" should not be used. Brazing of inhibited alpha brass flanges to copper pipes using rods of a 92,75 per cent copper–7,25 per cent phosphorus alloy has given satisfactory service. The alloy used for silver-brazing should contain not less than 49 per cent silver.

Mild steel flanges should be fusion welded or flash butt welded to mild steel pipes.

111 Alpha brasses must be properly inhibited against dezincification by suitable additions to the composition. Alpha-Beta brasses or those containing less than 70 per cent copper should not be used for pipes and fittings.

Design Considerations

112 In sea water, galvanic corrosion may cause premature failure of a component when it is in contact with one of a more noble metal. For guidance, Table R(D) 1.1 gives the galvanic series for common metals in sea water. A metal in direct contact with one lower in the list may suffer accelerated corrosion in sea water.

TABLE R(D) 1.1

GALVANIC SERIES IN SEAWATER

Zinc
Aluminium
Carbon Steel
Cast Iron
Lead-Tin Solders
Lead
Brasses
Copper
Phosphor Bronze
Gunmetal
Copper-Nickel-Iron Alloys
Aluminium Bronze
Monel Metal

Where components are made from different metals, preferential corrosion of the less noble metal may be minimised by the introduction of a sacrificial anode. This is made of a metal which is higher in the Table than either of the working metals. Where a sacrificial anode is used to provide local protection, there should be an efficient electrical bond between it and the metal which it is to protect.

113 Water speeds should be carefully assessed at the design stage and the materials of pipes, valves, etc., selected to suit the particular conditions.

114 Attention should be given to the design, fabrication and installation of systems to ensure streamlined flow. In particular, abrupt changes in the direction of flow, protrusions into bores of pipes and other restrictions of flow should be avoided.

Pipe bores should be smooth and clean. Any carbonaceous films or deposits formed on the bore surfaces of non-ferrous pipes during bending processes should be carefully removed. Jointing should be flush with the bore surfaces of the pipes. Branches preferably should be set at a shallow angle to the line of the main piping, the junction should be smooth and the branch should not protrude into the bore of the main pipe. Tight bends should be avoided. The bore surfaces should be smooth at these positions and free from puckering.

115 Very low water speeds and stagnant zones should be avoided. Systems should not be left idle for long periods especially where the water may be polluted.

116 Strainers should be provided at the inlets to sea water systems.

117 Non-ferrous pipes which are fairly heavily cold worked during fabrication should be annealed or stress relief heat treated before they are put into service. Finished aluminium or Admiralty brass pipes, in particular, should not be overstrained to facilitate alignment and tight joints.

Section 2

PIPES FOR FRESH WATER SERVICES

201 The corrosive conditions in fresh water systems are less severe than in sea water systems and generally mild steel or copper pipes are satisfactory for service in fresh water applications.

202 Mild steel pipes should not be left idle for long periods if the water has a low salt content. This low salinity and the limited supply of oxygen promote the formation of black iron oxide on the bores of the pipes which gives rise to severe corrosion of the pipes. Where stagnant conditions are unavoidable steel pipes should be galvanised or pipes of suitable non-ferrous material should be used. Hot fresh water may promote corrosion of mild steel pipe unless the hardness and pH of the water are controlled.

203 Copper alloy pipes should be treated by scouring or other means to remove any harmful cathodic films from the bores before pipes and tubes are despatched from the Makers' Works.

204 Brass fittings and flanges in contact with water should be made of an alpha brass which is inhibited against dezincification.

205 Aluminium brass pipes and fittings are not recommended for fresh water services as, under certain circumstances (not yet completely defined), premature failure by pitting and/or cracking can occur.

21st May, 1964

R (E)—GUIDANCE NOTES ON TORSIONAL VIBRATION CHARACTERISTICS OF MAIN AND AUXILIARY OIL ENGINES

Section 1

TORSIONAL VIBRATION CRITICAL SPEEDS AND LIMITING VIBRATION STRESSES

General

101 In oil engine installations torsional critical speeds occurring between idling and full speeds are generally inevitable and these guidance notes are intended to safeguard machinery from the effects of excessive torsional vibration during the life of the ship.

The stress limits recommended provide reasonable margins to avoid shaft fatigue failure. Critical speeds at which the stress limits would be exceeded, should be avoided for continuous operation.

Careful attention, however, should be given to the dynamic system at the design stage to ensure, in particular, that significant critical speeds requiring "barred" ranges are avoided within the speed range(s) proposed for continuous operation in service. *See* 104, "Barred" Speed Ranges.

The stress limits set out in the following paragraphs should not be viewed necessarily as design values, but rather as values which should not be exceeded where critical speeds of appreciable importance cannot reasonably be avoided.

The stresses considered in these notes are nominal values based on the plain section of the shafting, excluding stress raisers.

Between 90 and 100 per cent of the maximum continuous speed, the stress limits apply to the sum of the vibratory stress due to any resonant order and stresses due to the dynamically magnified portions only of the flanks of other significant orders (i.e., subtracting the stresses due to the exciting torques).

Where critical speeds are found by calculation to show stresses approaching the limits, torsiograph records may be required. In practice, differences between calculated stresses and stresses measured by torsiograph or equivalent are frequently found. Where such differences arise, the stress limits are to be applied to the measured stresses.

The stress limits are applicable to steel shafts having a tensile strength of 44 to 52 kg/mm^2 (28 to 33 ton/in^2). For shafts of high tensile steel or other material, the stress limits will be subject to special consideration.

Where the scantlings of crank shafts, webs, couplings, coupling bolts and straight shafting are greater than required by the Rules, higher vibratory stress limits may be considered.

Engine Speed R.P.M.

102 Maximum continuous speed N_S may be defined as the maximum revolutions per minute for which the engines are classed in continuous operation.

In the case of constant speed generating sets for main propulsion or auxiliary purposes N_S is taken as the full load R.P.M.

Any special speed requirements for prolonged periods in service should be indicated, e.g., range of trawling R.P.M., range of operating R.P.M. with controllable pitch propeller, idling R.P.M., etc. Such speed ranges should be maintained clear of significant critical speeds so far as practicable.

Governor Control

103 For closely governed installations, the application of formulæ 110 (4) and 111 (4) may be restricted to revolutions 5 per cent higher than the governor control limit, with a minimum of 1,10 N_S, provided such limit be demonstrated during engine trials.

"Barred" Speed Ranges

104 Where restricted speed ranges are imposed as a condition of approval, a notice board is to be displayed at the control station(s) stating that continuous operation should be avoided between the limits indicated by formulæ 110 (2) and 111 (2), and the tachometers marked accordingly. In such cases the tachometer accuracy should be checked against the counter readings, or by equivalent means, in the presence of the Surveyors to verify that it reads correctly within ± 2 per cent in way of the restricted range of revolutions.

Where vibration stresses due to criticals below 0,8 N_S marginally exceed the limiting stress for continuous operation, or where the critical speeds are sharply tuned, the range of revolutions restricted for continuous operation may be reduced.

Where such vibration stresses approach the limiting values f_t given in formulæ 110 (3) and 111 (3) the range of revolutions restricted for continuous operation may be extended, and the notice board(s) should indicate that this range must be passed through rapidly.

In cases where the resonance curve of a critical speed has been derived from torsiograph measurements, the range of revolutions to be avoided for continuous running may be

taken as that over which the measured vibration stresses are in excess of the limiting stresses for continuous operation, having regard to the tachometer accuracy.

Excessive Vibration Stresses

105 In cases where vibration stresses exceed the limiting values, the dynamic system should be re-designed, or damping or detuning arrangements provided to remove the critical speed from the operating range or to reduce the magnitude of the vibration stress.

It is preferable to avoid the use of dampers or detuners to control criticals within the range between 0,85 and 1,05 N_S, but if fitted they should be of a type which makes adequate provision for dissipation of heat and contain no mechanical parts subject to deterioration in service.

Where dampers or flexible couplings are fitted, it may be required that torsiograph records be taken to verify their efficacy.

Gear Hammer

106 In installations having reversing and/or reduction gearing, or geared scavenge blowers, etc., where the vibratory torques at the gears exceed the mean transmission torques at the criticals considered, it may be necessary to impose a restricted range of revolutions in way of each critical speed at which gear hammer occurs.

Further, in the event of gear hammer being detected at speeds other than the calculated critical speeds, torsiograph records may be required to confirm the calculated natural frequencies.

In all cases where there is a possibility of gear hammer, the backlash in the gears should be kept to a minimum.

At critical speeds near the maximum speed the vibratory torque should not, in general, exceed one-third of the full transmission torque. In cases where the proposed loading on the gear teeth is less than the maximum allowable special consideration will be given to the acceptance of additional vibratory loading on the gears.

Screwshafts

107 The stress limits for screwshafts apply to fully protected shafts having a continuous liner with efficient sealing arrangements against corrosion of the shaft by sea water, and to shafts without liner which are oil lubricated and which are fitted with an approved type of oil gland.

In other cases special consideration will be necessary.

The limits are intended to apply to the minimum section of the shaft between the forward end of the propeller boss and the forward stern gland.

Intermediate Shafts

108 The stress limits for intermediate shafts apply to shafts having integral flanges with Rule fillet radii.

Where loose couplings are employed, the vibration stresses in the shaft in way of the coupling should be limited to 75 per cent of these values.

Definition of Symbols

109 In the formulæ for determining vibration stresses, the symbols used are as follows:—

N = engine speed R.P.M.,
N_S = maximum continuous engine speed R.P.M. (*see* 102),
N_C = critical speed R.P.M.,
r = ratio N/N_S or N_C/N_S whichever is applicable,
d = minimum shaft diameter considered, in mm (in),
f_C = maximum value of the vibration stress for continuous running at or below maximum speed, in kg/cm² (lb/in²),
f_t = maximum value of vibration stress due to criticals below 0,8 N_S necessitating restricted ranges, in kg/cm² (lb/in²),
f = maximum value of the vibration stress above maximum speed, in kg/cm² (lb/in²).

Propelling Machinery—Vibration Stress Limits

Crank and Screw Shafts

110 Where the critical occurs at or below the maximum R.P.M., vibration stresses not exceeding values given by the following formula are considered satisfactory for continuous running, viz:—

$$f_C = \pm(315-0{,}22d)\,(1{,}6-r^2) \qquad (1)$$

$$\left(f_C = \pm(4500-80d)\,(1\cdot 6-r^2) \text{ British}\right)$$

Where the vibration stresses exceed the limiting values for continuous running as given by formula (1) a notice board should be fitted at control stations stating that the engine should not be run continuously between the following speed limits, above and below the critical speed, and the engine tachometers should be marked correspondingly, viz:—

Range of engine R.P.M. to be avoided:—

$$\text{From } \frac{16\,N_C}{(18-r)} \text{ to } \frac{(18-r)\,N_C}{16} \text{ inclusive} \qquad (2)$$

The maximum values of the vibration stresses due to such criticals should not exceed those given by the following formula, viz:—

$$f_t = 2\,f_C \qquad (3)$$

Criticals should be arranged sufficiently removed from the maximum R.P.M. to ensure that, in general, at $r = 0{,}8$ the stress due to the upper flank does not exceed f_C (formula (1)).

Where the critical occurs above the maximum R.P.M., the vibration stresses should not increase beyond values given by the following formula at revolutions up to 1,16 times the maximum R.P.M., viz:—

$$f = \pm (190-0{,}13d)\left(1 + 5\sqrt{r-1}\right) \quad (4)$$

$$\left(f = \pm (2700-48d)\left(1 + 5\sqrt{r-1}\right) \text{ British}\right)$$

Intermediate and Thrust Shafts

111 Where the critical occurs at or below the maximum R.P.M., vibration stresses not exceeding the values given by the following formula are considered satisfactory for continuous running, viz:—

$$f_c = \pm (535-0{,}22d)(1{,}44-r^2) \quad (1)$$

$$\left(f_c = \pm (7600-80d)(1{\cdot}44-r^2) \text{ British}\right)$$

Where vibration stresses exceed the limiting values for continuous running as given by formula (1), a notice board should be fitted at control stations stating that the engine is not to be run continuously between the following speed limits, above and below the critical speed, and the engine tachometers should be marked correspondingly, viz:—

Range of engine R.P.M. to be avoided:—

$$\text{From } \frac{16\,N_c}{(18-r)} \text{ to } \frac{(18-r)\,N_c}{16} \text{ inclusive} \quad (2)$$

The maximum values of the vibration stresses due to such criticals should not exceed those given by the following formula, viz:—

$$f_t = 1{\cdot}7\,f_c \quad (3)$$

Criticals should be arranged sufficiently removed from the maximum R.P.M. to ensure that, in general, at $r = 0{,}8$ the stress due to the upper flank does not exceed f_c (formula (1)).

Where the critical occurs above the maximum R.P.M., the vibration stresses should not increase beyond values given by the following formula at revolutions up to 1,16 times the maximum R.P.M., viz:—

$$f = \pm (235-0{,}097d)\left(1+5\sqrt{r-1}\right) \quad (4)$$

$$\left(f = \pm (3340-35d)\left(1+5\sqrt{r-1}\right) \text{ British}\right)$$

Auxiliary Machinery and Propulsion Oil Engine Driven Generators

112 The following notes are applicable to oil engines developing 150 bhp or 100 kW and over, driving auxiliary machinery used for essential services and to propulsion oil engine driven generating sets operating at constant speed.

The dynamic system comprising engine and driven machinery should be so designed that vibration stresses in the crank shafts and transmission shafting resulting from critical speeds do not exceed values given by the following formula within speed limits of 0,95 and 1,10 N_S, N_S being the full load R.P.M., viz:—

$$f_c = \pm (212-0{,}14d) \quad (1)$$

$$\left(f_c = \pm (3000-50d) \text{ British}\right)$$

Vibration stresses in the crankshaft and transmission shafting due to critical speeds which have to be passed through in starting and stopping should not exceed values given by the following formula, viz:—

$$f_t = 5{,}5f_c \quad (2)$$

Furthermore, the amplitudes of vibratory inertia torque imposed on generator rotors should be limited to $\pm$ 2,0 Q_S over the speed range from 0,95 to 1,10 N_S and to $\pm$ 6,0 Q_S in passing through criticals below 0,95 N_S, where Q_S is the rated full load mean torque.

The rotor shaft and structure should be designed to withstand the foregoing magnitudes of vibratory torque.

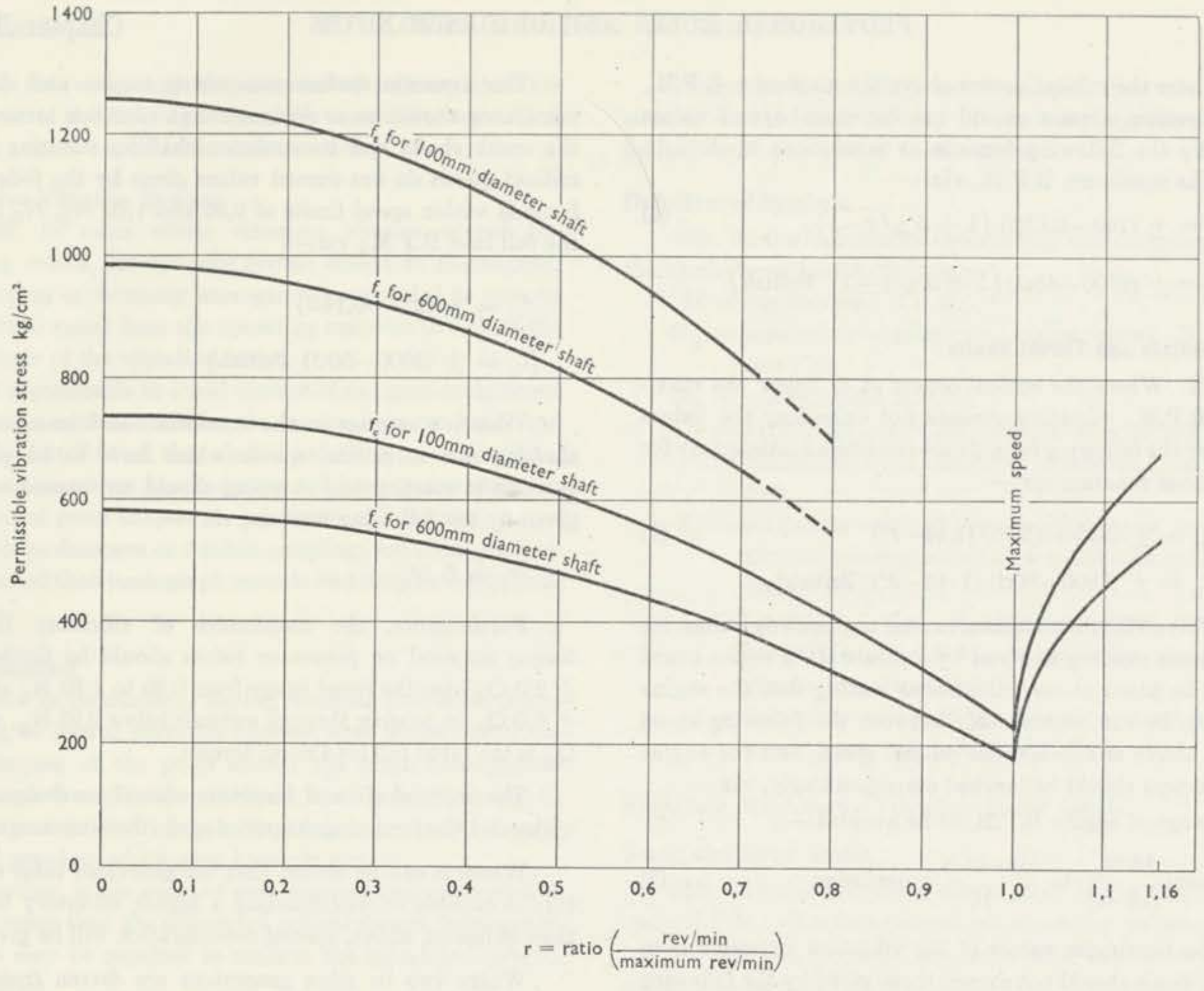
Where it can be shown that the generator rotor structure is capable of withstanding a higher vibratory torque than indicated above, special consideration will be given.

Where two or more generators are driven from one engine, each generator should be considered separately in relation to its own designed rated torque.

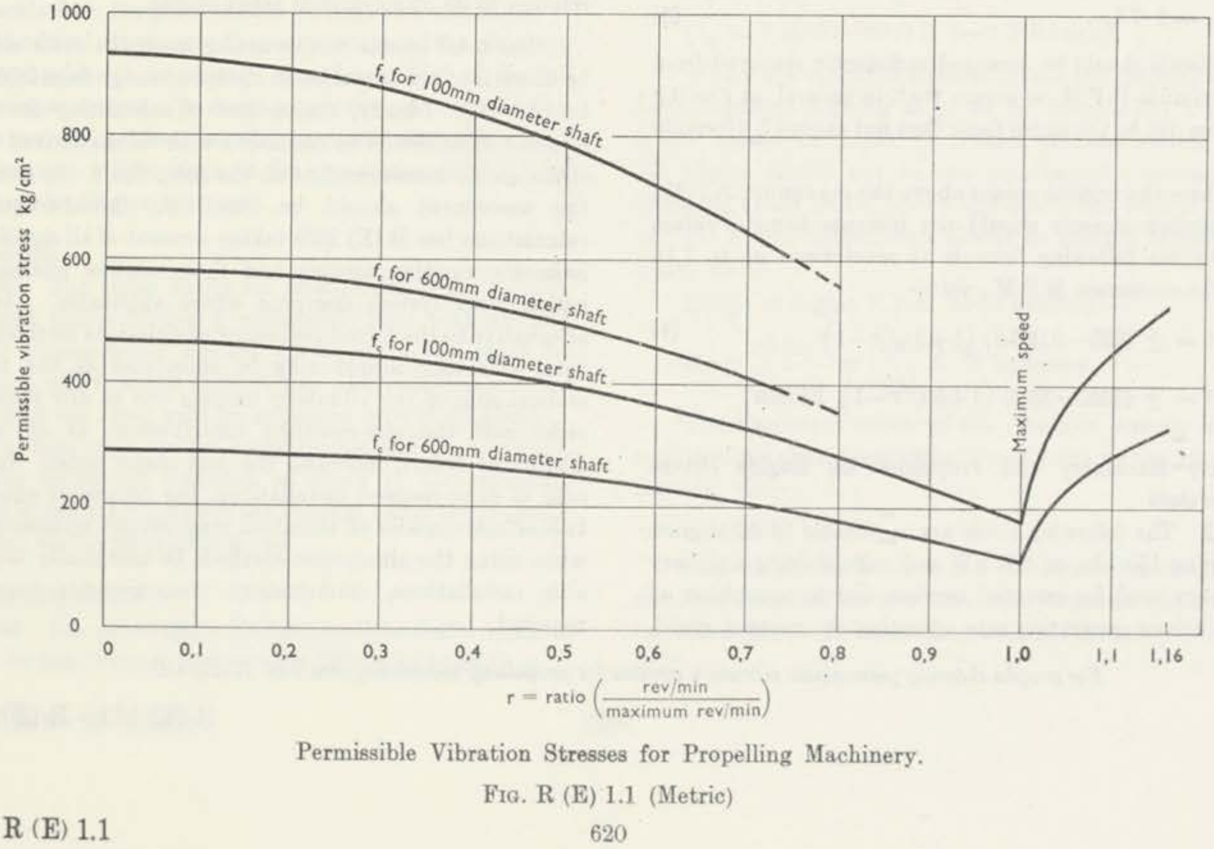
The total inertia torque acting upon the rotor should be taken into consideration in the speed range from 0,95 N_S to 1,10 N_S. Ideally, the method of calculating the total inertia torque should be consistent with values derived from strain gauge measurements on the rotor shaft. In general, the assessment should be based on forced-frequency calculations (*see* R (E) 225) taking account of all significant harmonic exciting torques and their relative phases, together with system damping where applicable. As an alternative to the forced-frequency calculations method, the total vibratory torque may be calculated as the arithmetical sum of the vibratory torques due to any resonant order and the non-resonant contributions of all other significant orders, including the first major order. In the case of close-coupled installations, the combined effect of two or more modes of vibration may require consideration when using the alternative method. In marginally acceptable installations, confirmatory measurements may be required.

For graphs showing permissible vibration stresses for propelling machinery, see Fig. R (E) 1.1

INTERMEDIATE & THRUST SHAFTS

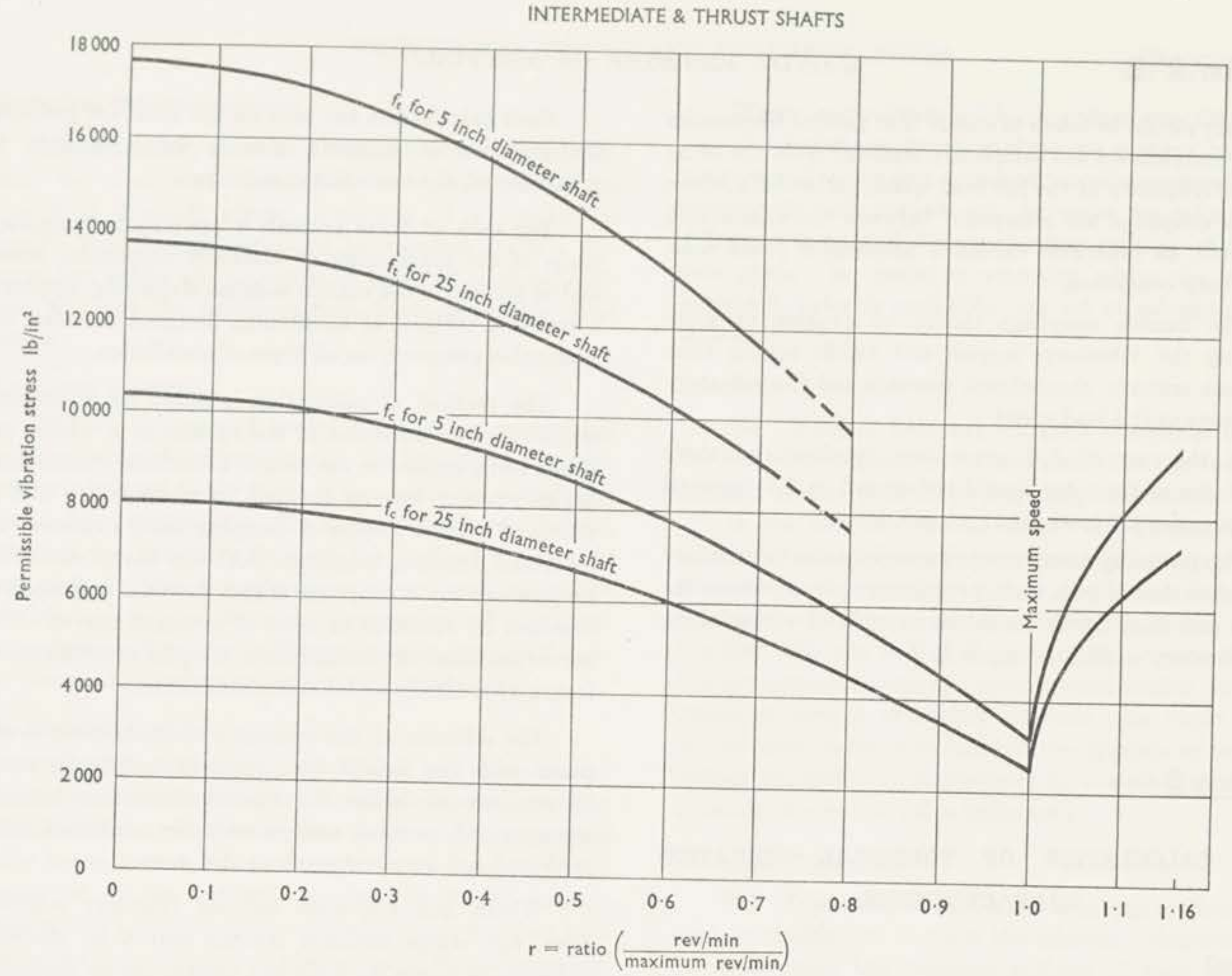


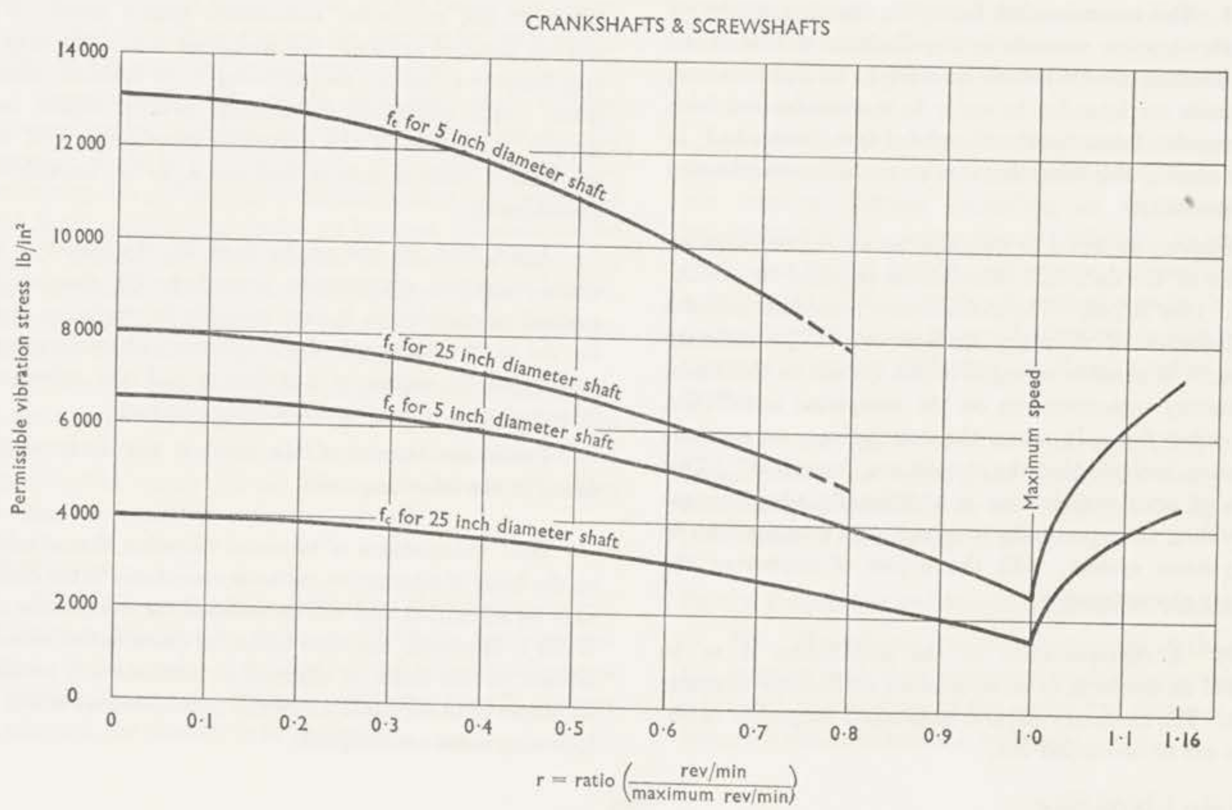
CRANKSHAFTS & SCREWSHAFTS



Permissible Vibration Stresses for Propelling Machinery.

FIG. R (E) 1.1 (Metric)





Permissible Vibration Stresses for Propelling Machinery.

FIG. R (E) 1.1 (British)

Care should be taken to ensure that natural frequencies of the complete set are sufficiently removed from the firing impulse frequency at the full load speed, particularly where flexible couplings are interposed between the engine and generator, as otherwise excessive amplitudes could arise under such conditions.

The flexible couplings should be capable of withstanding the vibratory torques and twists arising from transient criticals, short-circuit currents and the vibratory conditions at full load speed.

In the case of A.C. generators, resultant vibratory amplitudes at the rotor should not exceed $\pm$ 2,5 electrical degrees under full load working conditions.

The foregoing recommendations apply also to auxiliary generators driven from main propulsion systems, where the rotors and their drives should be capable of withstanding the vibratory conditions imposed.

Section 2

THE CALCULATION OF TORSIONAL VIBRATION CHARACTERISTICS

General

201 The recommended limits for the magnitudes of torsional vibration stresses in the shafting of marine oil engine installations are set out in R (E) 1. In a strict sense, these limits are intended to apply to stresses derived from measurements taken on the completed installation and, in cases of doubt, this basis remains as the ultimate criterion of acceptability.

However, approval is desirable at an earlier stage on the basis of the data and calculations required to be submitted. (*See* H 242). The examination procedure includes the calculation of vibratory stresses and, in the majority of cases, it is possible to approve the system on this basis, confirmatory measurements on the completed installation being called for only when the calculations, or previous experience, indicate that the stresses are "marginal". This process of prior examination is additionally advantageous in providing an opportunity to recommend modifications to the dynamic system, with the object of improving the vibratory characteristics.

202 A representation of the installation is to be prepared in the form of an equivalent multi-mass dynamic system. The necessary natural undamped frequency calculations are to be carried out.

Such calculations are used as the basis for predicting the positions of resonant criticals within, and in the proximity of, the operating speed range.

For each of these criticals a preliminary estimate is made of the magnitudes of vibratory amplitude, stresses and/or torques in the various sections of shafting, employing a standard method of calculation, designed to cater, with reasonable accuracy, for all types of installation.

The method of calculation is based on a simplified semi-empirical treatment of the system as a whole, excitation being applied in the form of a vectorial summation of engine exciting torques for each harmonic order, and the effects of various sources of damping being expressed as a combined dynamic magnifier. Both the harmonic exciting torques and the appropriate engine dynamic magnifiers are obtained by reference to a set of averaged curves. These curves are based on the analysis in the past of measurements from a wide variety of different installations.

The estimate of the vibratory characteristics is compared with the results from previous sufficiently similar installations (to allow for typical departures from the average) and, in most cases, acceptable conditions can be predicted and approval given at this stage.

Where, however, more complex vibratory conditions arise, e.g., where resonant criticals cannot be treated in isolation, or where the flank of a critical has an appreciable effect at the maximum continuous engine speed, or in heavily damped systems, the simplified treatment may be insufficiently revealing, necessitating more detailed calculations. Such additional calculations usually require more specific knowledge of the particular installation and vary too widely, both in nature and scope, to be amenable to generalisation.

Apart from its use as the basis for the Society's torsional vibration examination procedure, the standardised method of calculation is also valuable in providing means for the early assessment of the vibratory characteristics of new types of engine or installation and the subsequent interpretation of torsiographic measurements.

Particular aspects of the method are dealt with in detail in the following notes.

203 Calculations of torsional vibration characteristics on the basis of alternative methods acceptable to the Society may be submitted and will be assessed for compliance with R (E) 1. However, the time taken for examination of calculations on the basis of alternative methods will normally be longer than for cases where the procedures set out in the following notes are adopted.

Equivalent Dynamic Systems

204 For the purposes of torsional vibration calculations the machinery installation is represented by an equivalent dynamic system consisting of a number of discrete rigid inertias separated by massless shafts. The equivalent shafts are expressed in terms of torsional stiffness, although the reciprocal form is an acceptable alternative.

Referred Systems

205 In the case of geared installations, comprising shafts rotating at different speeds, the equivalent dynamic system is referred to the speed of the engine crankshaft, for ease in later calculation. For multi-engined installations, although the basic principles of the method are equally applicable, special considerations associated with the possible variations in the mode of operation and indeterminate phasing of engines, will require some modification to the standard procedure and mode of presentation.

Crankshaft Systems

206 The engine system is divided into a number of inertias, each concentrated at the cylinder centre line. The effective inertia per cylinder line is taken as the average value throughout a cycle of rotation and consists of the inertia of all the rotating elements, including balance weights and a portion of the connecting rod, together with the inertia given by one half of the mass of the reciprocating elements considered concentrated at the crank pin radius. In the case of a "Vee" engine, the inertias for each pair of cylinders are combined into a single inertia.

Accurate estimation of the equivalent shaft stiffness between engine cylinder centres is complicated by the irregular shape of the crankshaft. Numerous formulæ for evaluating the stiffness per crankthrow have been published and their applicability varies as between different engine types. Enginebuilders are advised to check the validity of their estimates for new crankshaft designs, either by static stiffness tests or indirectly by natural frequency measurements for the crankshaft mode of vibration.

(A similar difficulty in assessing shaft stiffnesses occurs in some types of driven machinery, particularly in the case of rotor shafts in close-coupled generator installations, and experimental means should likewise be employed where necessary to verify the estimated values).

Propellers

207 It is necessary in estimating the effective inertia of marine propellers to make an allowance for entrained water. In the absence of detailed information, this allowance is taken as 25 per cent. Where a value other than 25 per cent is adopted, the amount is to be stated.

Where controllable pitch propellers are fitted, two sets of calculations, based on dynamic systems having 25 per cent and 10 per cent entrained propeller water allowance respectively are carried out, in order to estimate the difference in natural frequency when working at full and zero pitch. In modes of vibration where the effect of entrained water is negligible, one set of calculations will suffice.

Dampers

208 Where a torsional vibration damper is fitted to the machinery, this is to be represented in the equivalent dynamic system used in the frequency calculations.

In the case of "viscous shear" or "slipping torque" types of damper, where the seismic mass is not mechanically connected to the rest of the system, the damper is represented by an effective inertia comprising the casing or hub, together with one half of the inertia of the seismic mass. For dampers consisting of a seismic mass flexibly driven by means of springs or rubber elements, the whole of the seismic mass inertia is included in the dynamic system. The flexible connection is represented by a shaft stiffness, the dynamic or effective value being used.

Flexible Couplings

209 Torsionally flexible shaft couplings are frequently used to modify and improve the vibratory characteristics. In many cases the torsional stiffness of such couplings varies as between static and dynamic conditions of loading, and, wherever possible, the effective dynamic stiffness as determined by experiment is to be used in compiling the dynamic system.

Certain types of flexible couplings are designed with non-linear or discontinuous torque/deflection characteristics, the torsional stiffness depending on the magnitude of transmitted torque and/or speed of rotation. In such cases, depending on the relative importance and position in the speed range of the significant critical speeds, it may be necessary to calculate natural frequencies on the basis of a range of coupling stiffnesses in the equivalent dynamic system.

210 The particulars of the equivalent dynamic system should be summarised in tabular form, together with other relevant data for use in subsequent calculations. (*See* Tables R (E) 2.1a and 2.1b).

Natural Frequencies and Associated Modes of Vibration

211 The natural torsional frequencies of the installation together with their associated modal characteristics are calculated on the basis of the equivalent dynamic system, using the Holzer tabulation technique.

The number of modes requiring to be investigated varies as between different installations, but the search should be carried out up to a frequency equivalent to 15 times the maximum continuous speed of the engine. This ensures that it will be possible in later calculations to account for critical resonant conditions arising from all harmonic torque excitations up to order 12, in a speed range extending up to 125 per cent of the maximum continuous engine speed.

212 The information obtained from the natural frequency calculations for each mode of vibration should be summarised as in Table R (E) 2.2.

The relative amplitude in Col. 2 of the Table is arranged to have a value of unity at the mass position corresponding to engine cylinder No. 1 (i.e. the cylinder farthest removed from the driven machinery). Consequently the vibratory torques listed in Cols. 3 and 4 and the shaft stresses in Col. 6 relate to a modal amplitude of 1 radian at engine cylinder No. 1. From these values of relative amplitude, phase-vector sums are calculated and tabulated for all relevant modes. (Table R (E) 2.3). In addition, the stress factors listed in Col. 6 are corrected for the actual shaft speed, the reduction gear ratio, where applicable, having been taken into account.

The Prediction of Vibratory Magnitudes by Calculation

213 Each torsional mode of vibration having a natural frequency, F, cycles/min, is excited by the harmonic components of the applied torque, the order number of each harmonic being denoted by m. Resonant conditions associated with these harmonic orders of excitation arise at a series of critical running speeds, given in general by

$$N_c = F/m \quad \text{R.P.M.}$$

214 The magnitudes of vibration are to be estimated for all such critical conditions occurring in a speed range extending from 10 per cent up to 125 per cent of the maximum continuous engine speed, N_s.

For each critical speed, N_c, considered, the amplitude of torsional vibration, θ_1, at engine cylinder No. 1 is given by

$$\theta_1 = \pm\, M\, \theta_0 \text{ radians,}$$

in which,

M = dynamic magnifier for the whole system, (*See* 217 to 222),

$$\theta_0 = \frac{T_m\, A\, R\, \Sigma\vec{\Delta}}{\omega^2\, \Sigma\, (J\,\Delta^2)} \text{ radians,}$$

T_m = resultant m^{th} order harmonic component of tangential effort at each crankpin, expressed per unit area of piston, in kg/cm² (lb/in²), (*See* 216),

A = area of each piston, in cm² (in²),

R = crank radius, or mean crank radius for opposed piston engines, in cm (in),

$\Sigma\vec{\Delta}$ = phase-vector sum for all engine cylinders, (Table R (E) 2.3), derived from the frequency table relative amplitudes and the m^{th} order phase angle diagram.

ω = natural phase velocity of the mode of vibration, in rad/sec,

$\Sigma\,(J\,\Delta^2)$ = summation of terms, obtained from the natural frequency table (Table R (E) 2.2), for the whole system, in kg cm sec² (lb in sec²).

215 Having calculated the vibratory amplitude, θ_1, the corresponding stress in any shaft in the system is obtained by multiplying θ_1 by the appropriate stress factor in Col. 6 of the tabulated natural frequency data. (Table R (E) 2.2).

By a similar process of scaling, magnitudes of vibratory amplitude and torque, where these quantities are of interest, are predicted for any part of the system, making use of the entries in the appropriate columns of the Table.

Thus, for example, in geared installations, predictions relating to the likelihood of vibratory torque reversal, and hence "gear-hammer", arising at resonant conditions are based on a comparison between the estimated vibratory torque occurring at the gear mesh and the mean driving torque transmitted at the particular running speed. In this connection, the inertia of the gearing is split into driving and driven components in the natural frequency calculations, thereby permitting a better assessment of the vibratory torque at the actual gear mesh.

As a further example, in the case of generator installations, a comparison is required between the vibratory inertia torque imposed on the armature and the full load mean torque. Here the inertia torque is obtained from the appropriate entry in Col. 3 of the tabulated data (Table R (E) 2.2).

Harmonic Torque Components

216 Figs. R (E) 2.1a and 2.1b give averaged curves of resultant components of tangential effort (T_m) per unit area of piston, plotted against cylinder mean indicated pressures, for each harmonic order, m.

Although presented in a form suitable for 4-stroke engines, the curves for the integral order harmonics apply equally to 2-stroke engines (including opposed piston engines), the appropriate values being doubled.

Inertia torque components, due to the reciprocating parts, have not been taken into account in these curves and the values used for the first three integral order harmonics require suitable correction in individual cases.

In certain installations it may be necessary to consider excitation from the propeller as well as from the engine.

Dynamic Magnifiers

217 Although the method already described for calculating magnitudes of vibration at critical speeds involves the use of a dynamic magnifier applying to the system as a whole, the more important sources of damping are determined individually. The partial dynamic magnifiers so obtained are then combined on an empirical basis to give an overall magnifier for the complete system. (*See also* 222).

Engine Magnifier

218 The dynamic magnifier associated with the effects of damping arising within the engine, M_E, is expressed as a function of θ_o,

$$M_E = 3{,}8 \ \theta_o^{-\frac{1}{4}}$$

For convenience, this expression is given in graphical form in Fig. R (E) 2.2.

In practice, the value of M_E, so obtained, is limited to a maximum of 50.

In installations where the engine provides the only appreciable source of damping, or in modes of vibration insensitive to damping arising elsewhere, the engine magnifier, M_E, becomes the effective magnifier, M, for the whole system.

Propeller Magnifier

219 Propeller damping, which assumes importance in the case of shafting modes of vibration of propulsion machinery, is taken into account by the use of a propeller dynamic magnifier, M_P, determined from the following formula:—

$$M_P = \frac{\Sigma (J\,\Delta^2)\, N_s^3\, m}{680\,000\, a\, H\, \Delta^2_p}$$

$$\left(M_P = \frac{\Sigma (J\,\Delta^2)\, N_s^3\, m}{600\,000\, a\, H\, \Delta^2_p} \right) \quad \text{(British)}$$

in which

$\Sigma (J\Delta^2)$ = summation of terms for the whole system, in kg cm sec², (lb in sec²),

N_s = maximum continuous engine speed, R.P.M.,

m = harmonic order number,

H = rated brake horsepower at the maximum continuous engine speed, Metric (British),

Δ_p = relative modal amplitude at the propeller, radians, (referred to crankshaft speed in the case of a geared installation),

a = coefficient, taken as 30 (average value),

$$= \frac{K_p\, N_c}{Q_c}$$

where

K_p = propeller damping coefficient, in kg cm sec/rad (lb in sec/rad),

Q_c = mean propeller torque at critical speed, in kg cm (lb in),

N_c = propeller speed at critical, R.P.M.

Where the propeller design is such as to indicate that its damping properties may be other than the average assumed in the above formula and also in the case of a controllable pitch propeller, an appropriate adjustment to the coefficient, a, may be accepted, based on the geometrical parameters of the propeller, or on the evidence of measured results.

Vibration Damper Magnifiers

220 Vibration dampers in general vary widely in their mode of operation. Assessment of the damping properties of a particular combination of damper and engine system, together with the corresponding equivalent damper magnifier, M_D, should be carried out in consultation with the damper manufacturers and the predictions verified by practical measurement on a typical installation. (*See* R (E) 105).

In the particular case of a viscous-shear type of damper, the additional damping influence (assumed to be under optimum conditions of tuning) is calculated by taking a dynamic magnifier

$$M_D = \frac{2{,}0\, \Sigma (J\,\Delta^2)}{J_R\, \Delta_D^2}$$

where

$\Sigma (J\Delta^2)$ = summation for complete system, including contribution from the effective damper inertia,

J_R = moment of inertia of the seismic mass,

and Δ_D = relative modal amplitude at damper casing.

Flexible Couplings

221 Many types of flexible couplings, apart from providing convenient means for modifying and improving the natural frequency characteristics of machinery installations, also are designed to have a controlling influence on the systems under resonant conditions, either by the incorporation of true damping principles or by virtue of detuning effects produced by non-linear torque/deflection relationships. This ability to reduce the magnitude of resonant criticals is usually confined to modes of vibration having appreciable relative angular deflections across the coupling elements. The manufacturers should be consulted regarding the appropriate characteristics of the coupling with reference to energy loss/cycle, and for novel types the value assumed is to be confirmed by measurement on a typical installation.

Combined Dynamic Magnifier

222 The overall dynamic magnifier, M, for the system as a whole is obtained by combining the magnifiers, estimated for the individual sources of damping, in the following empirical manner:—

$$M = \left[\left(\frac{1}{M_E}\right)^2 + \left(\frac{1}{M_P}\right)^2 + \left(\frac{1}{M_D}\right)^2 + \cdots\right]^{-\frac{1}{2}}$$

Non-Resonant Conditions

223 The procedure outlined in the previous Sections is intended to provide means for predicting magnitudes of vibration at resonant criticals in the operating speed range.

In many cases, however, levels of vibration, sufficiently high to warrant further consideration, may occur under non-resonant conditions away from critical speeds.

This situation frequently arises near the maximum continuous engine speed where the machinery may be operating on the flank of a particularly powerful critical, or where the cumulative effect of a complex of resonant criticals and flank conditions, attributable to several orders of harmonic excitation, may have to be taken into account.

224 The normal procedure for estimating the magnitude of vibration on the flank of a single critical is to calculate first the amplitude, θ_O at resonance (as in 214). The amplitude θ_F for the flank condition (corresponding to θ_1), is then obtained from the following formula:—

$$\theta_F = \pm\,\theta_O \left[\left\{1 - \left(\frac{N}{N_C}\right)^2\right\}^2 + \left(\frac{N}{N_C}\right)^2 \frac{1}{M^2}\right]^{-\frac{1}{2}}$$

where

N = engine speed at the required flank condition,

N_C = critical speed,

M = dynamic magnifier at resonance.

The required magnitudes of flank amplitude, torque and stress in the system are deduced from the application of θ_F as a scaling factor to the tabulated natural frequency data (Table R (E) 2.2), on the assumption that the latter remain valid for the flank conditions as well as for resonance, which is normally sufficiently accurate. If the harmonic torque component at the engine speed considered differs appreciably from that at the critical speed, the former value is used as the basis for calculating θ_O.

225 The foregoing approach, in which a particular non-resonant operating condition is considered to be situated on the flank of an adjacent isolated critical may, in certain cases, be an over-simplification. This situation arises in systems having a number of natural frequencies fairly close to one another, such that a single harmonic order appreciably excites several modes of vibration, whose contributions to the total vibratory conditions cannot be ignored. In these circumstances the vibratory conditions are to be investigated by non-resonant forced frequency tabulation techniques, and where damping has an important influence, this is to be included in the calculation procedure.

15th January, 1970

TABLE R (E) 2.1a

PARTICULARS OF OIL ENGINE MACHINERY

Ship's Name:—
Description and Class:—
Shipbuilders:—
Enginebuilders:—
Description of Machinery:—

Yard No.
Engine No.

Engine Data:—

Type:—
Cycle:—
No. of Cylinders:—
Bore:—
Stroke:—
"Vee"-angle:—
Firing Order:—

Max. Press.:—
M.I.P.:—
Max. cont. engine BHP:—
Max. cont. engine RPM:—
Idling RPM:—
Balance Wts. disposition:—
inertia:—
Span of Bearings:—
Crankshaft Plan No.:—

Propeller and Shafting Data:—

Propeller Dia.:—
No. of Blades:—
Fixed Pitch/C.P.:—
Inertia (dry):—
Propeller Plan No.:—

No. of Screwshafts:—
Max. cont. RPM:—
Working Range of RPM:—
Cont. Liner/Oil Gland:—
Shafting Layout Plan No.:—

Auxiliary Machinery Data:—

Rotor Shaft Plan No.:—

Generator Make and Type:—
Rating AC/DC, KVA/KW, full load/no load RPM:—
Whether Unit on Resilient Mountings:—

Gearing Data:—

Gearing Plan No.:—

Make and Type:—
Speed Ratios:—

Vibration Damper Data:—

Make and Type:—
Seismic Mass Inertia:—
Hub or Casing Inertia:—
Spring Stiffness, Static/Dynamic:—
Damping Coefficient:—

Flexible Coupling Data:—

Make and Type:—
Stiffness, Static/Dynamic:—
Max. Cont. Vibratory Torque:—
Coupling Damping:—

Additional Features

TABLE R (E) 2.1b

Equivalent Dynamic System:—

Mass Number	Description	Inertia J kg cm sec^2 (lb in sec^2)	Shaft Stiffness C 10^6 kg cm/rad (10^6 lb in/rad) or I/C	Minimum Shaft Diameter d cm (in)	Shaft Speed reduction G	Engine Cylinder firing angles, degrees	
						A	B

NOTES:—TABLE R (E) 2.1b

The minimum sectional modulus of the shaft in torsion, Z, in cm^3 (in^3), is to be stated where the shaft is not of solid circular cross-section.

The speed reduction, G, in a geared system is related to the crankshaft speed, i.e. G = crankshaft speed/shaft speed.

The cylinder firing angles are to indicate the true angular position for each cylinder in the firing sequence whether 2- or 4-stroke cycle. For "Vee" engines the firing angles for both cylinders on one pin are required at each crank.

Columns A and B relate to the cylinder banks of a "Vee" engine. In the case of an "In-line" engine only one column is required.

TABLE R (E) 2.2

Frequency, F = C.P.M. No. of Nodes = $\omega^2 =$

Col. 1.	Col. 2.	Col. 3.	Col. 4.	Col. 5.	Col. 6.
Mass Number	Relative Amplitude Δ (Radians)	Inertia Torque $J\,\omega^2\Delta/10^6$ 10^6kg cm (10^6lb in)	Modal Shaft Torque $\Sigma J\,\omega^2\Delta/10^6$ 10^6kg cm (10^6lb in)	$J\,\Delta^2$ kg cm sec² (lb in sec²)	Nominal Shaft Stress Factor $\frac{G}{Z}\Sigma\frac{J\,\omega^2\Delta}{10^6}$ 10^6kg/cm² (10^6lb/in²)*
			$\Sigma(J\,\Delta^2) =$		

ω = Natural phase velocity of the mode of vibration (rad/sec),

F = Natural frequency of vibration (cycles/min).

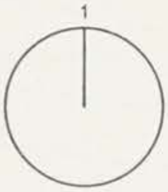
$$F = \frac{60\,\omega}{2\,\pi}$$

(For definition of other symbols see Table R (E) 2.1b)

* Per radian at No. 1 cylinder

TABLE R (E) 2.3

Crank Arrangement



Vector Summation

Orders	Resultant for 1 radian at No. 1 cylinder		
	1-node	2-node	3-node

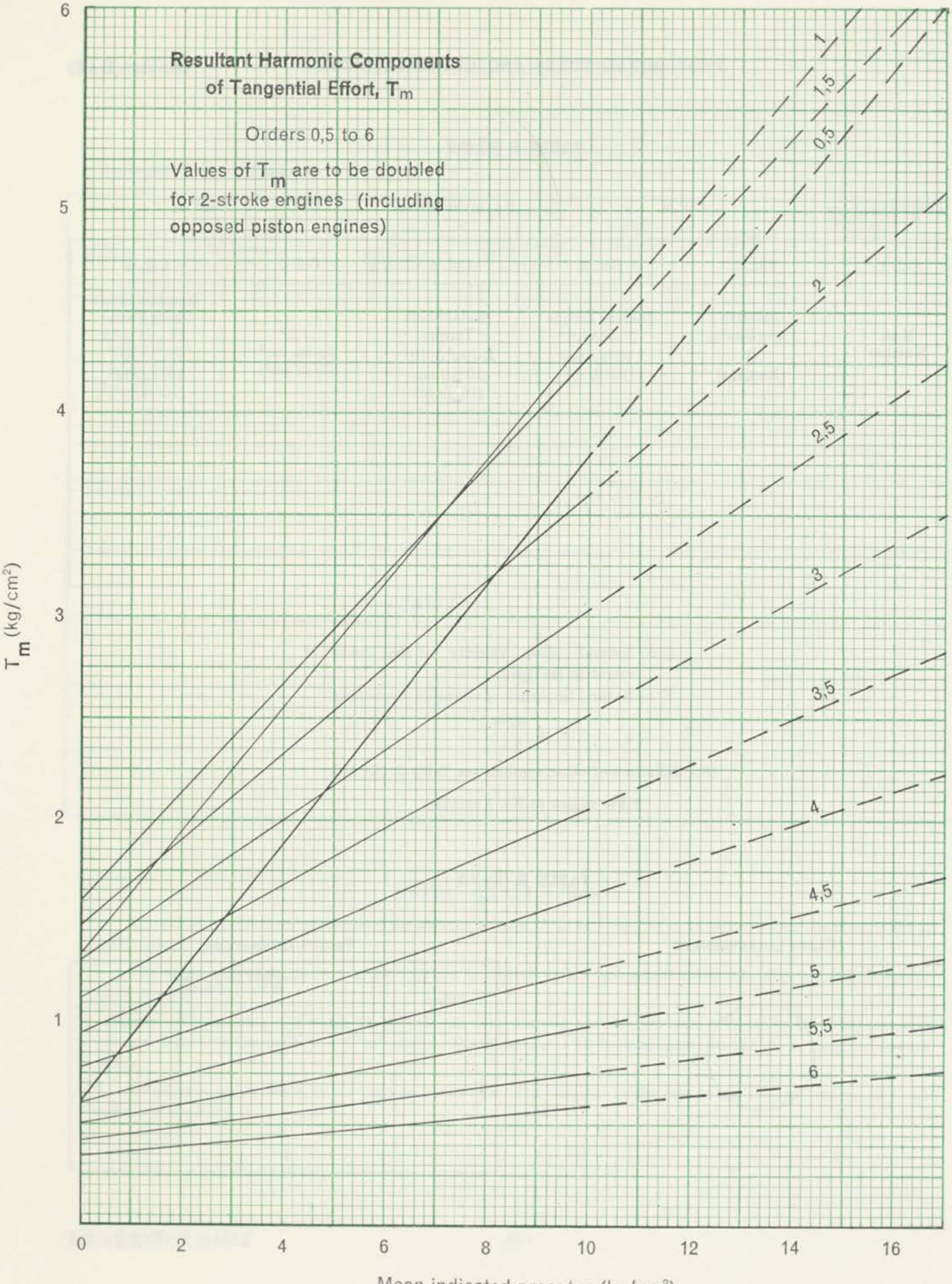


FIG. R (E) 2.1a (Metric)

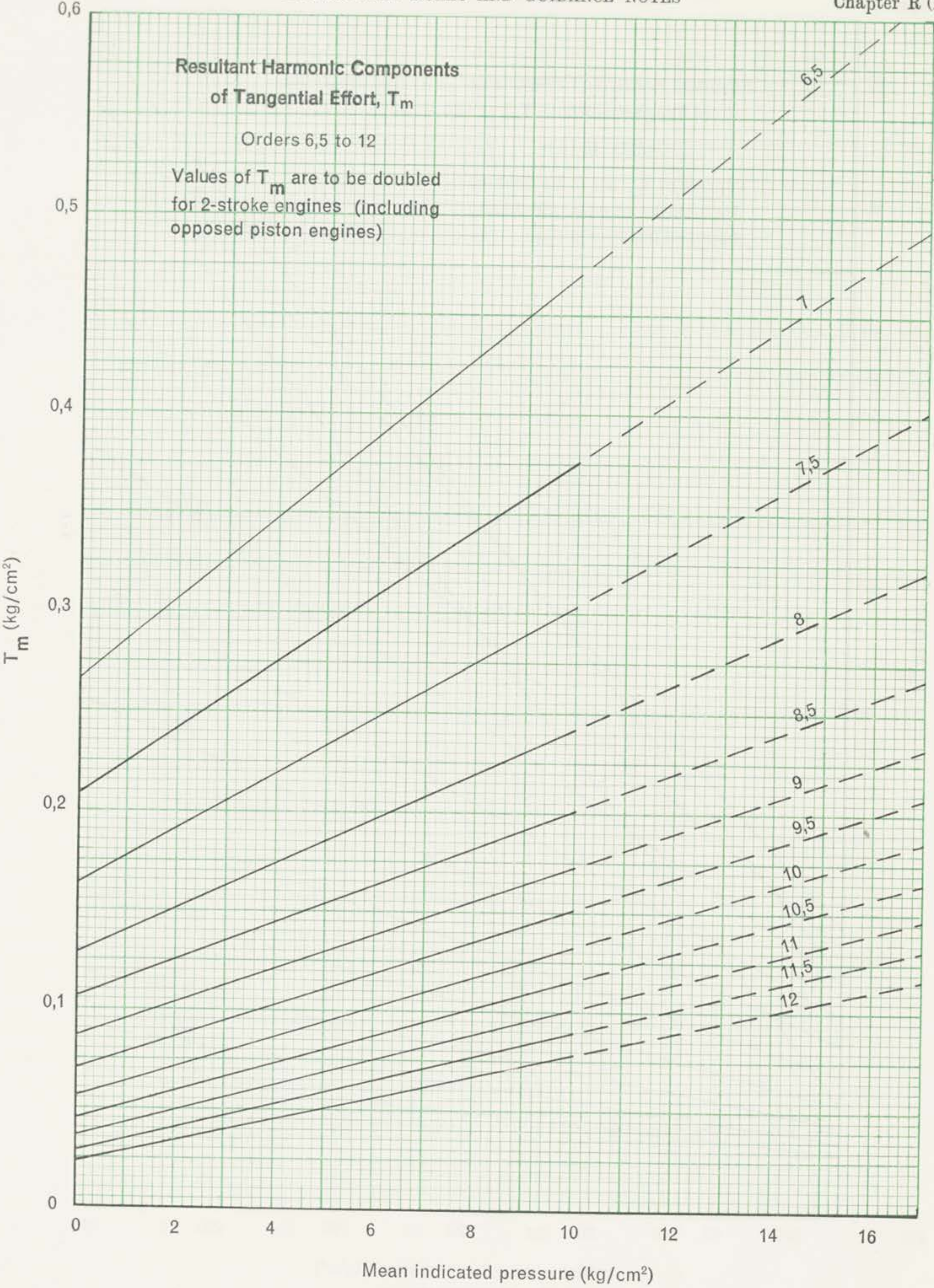


FIG. R (E) 2.1b (Metric)

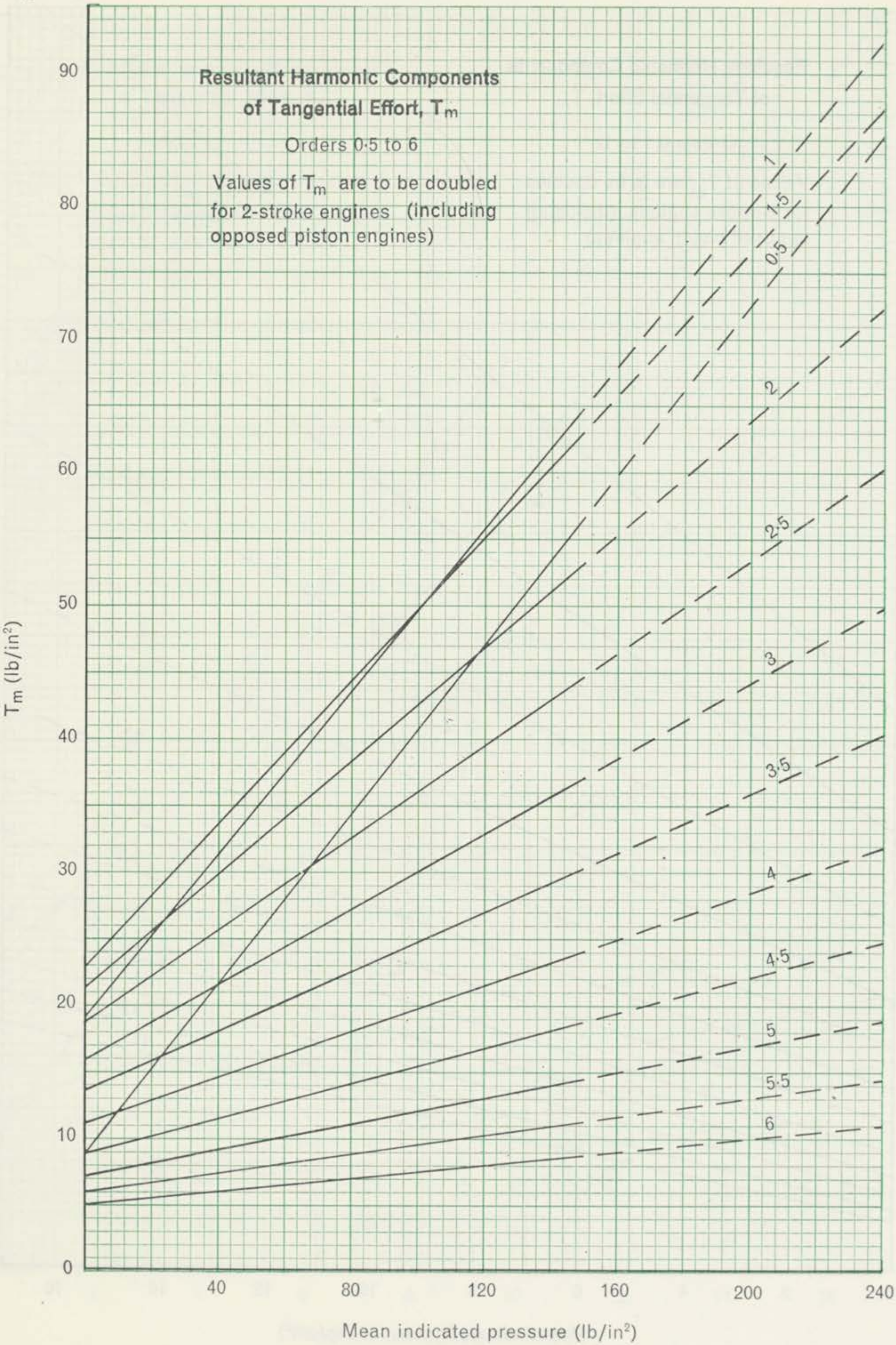


Fig. R (E) 2.1a (British)

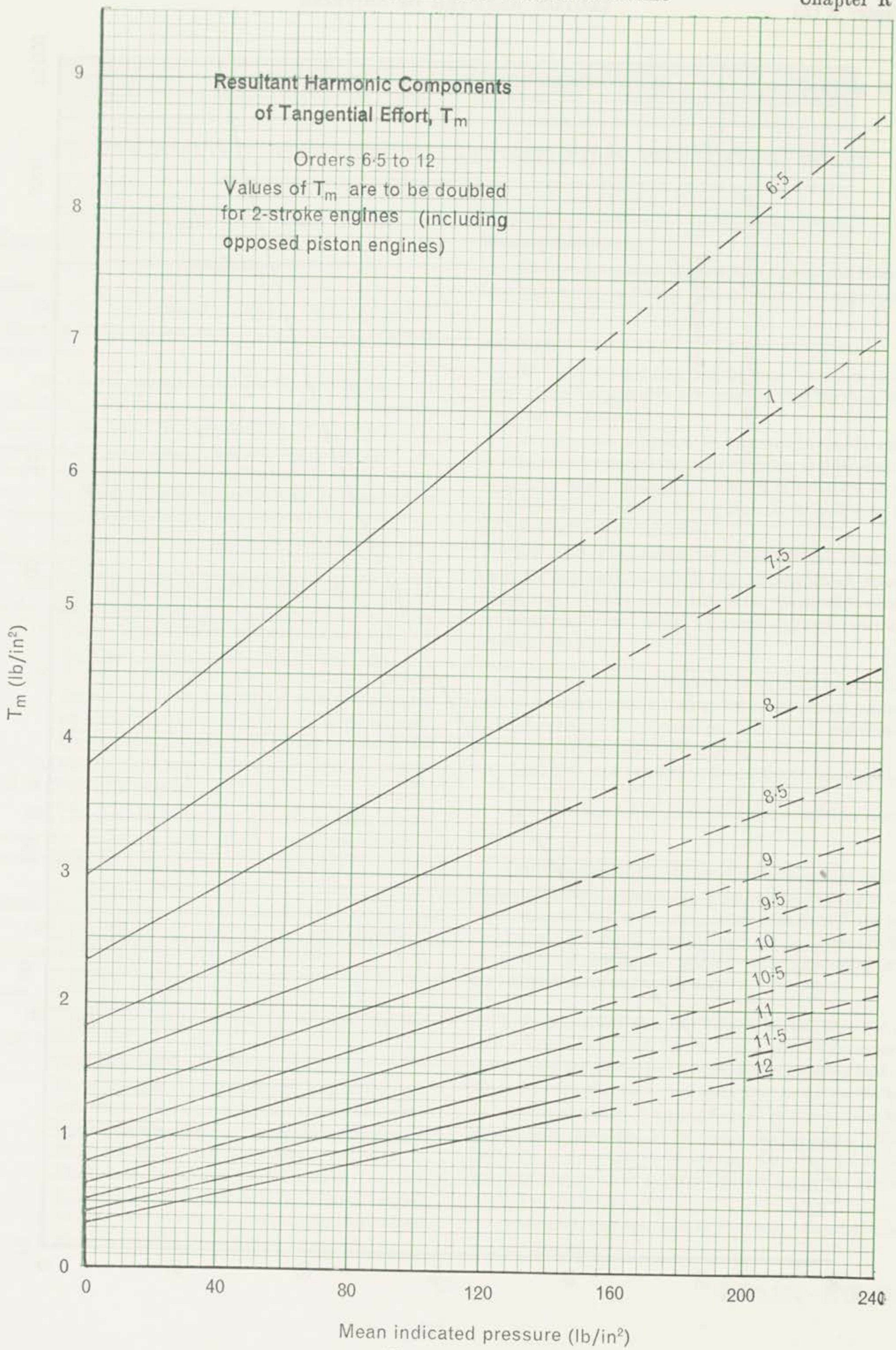


FIG. R (E) 2.1b (British)


Engine dynamic magnifier (M_E)
M_E = 3,8 θ_0^-¼
θ_0 (10^-6 radians)
10
50
100
500
1000
5000
10 000
M_E
0
10
20
30
40
50
60

Fig. R (E) 2.2

R (F)—PROVISIONAL RULES FOR THE CLASSIFICATION OF FLOATING DOCKS

Section 1

GENERAL

Class

101 The class assigned to Floating Docks will be "A" "Floating Dock. For service at .... (port to be specified)".

102 The requirements of this Chapter indicate the general standards required by the Society for the classification of floating docks. In view, however, of the variations in operating conditions for which docks may be designed, the Society will give special consideration to other design criteria. Where considered necessary, an appropriate notation will be added to the class assigned.

General Design

103 The requirements apply directly to floating docks of the following types:—

(a) Caisson type, in which the bottom caisson and both wing walls are continuous and inseparable.

(b) Pontoon type, in which the wing walls are continuous and the bottom is formed of non-continuous pontoons. The pontoons may be either permanently attached to the wing walls or may be detachable.

The scantlings and arrangements of docks of other types will be specially considered.

104 The preceding Chapters of the Rules apply as may be relevant to floating docks except as otherwise required by the following.

Material

105 The mild steel used for the main structural members of the dock shall comply with D 104.

Plans

106 The following plans are to be submitted for approval:—

Section at mid-length.

Structural plan of wing walls, top deck, safety deck and, for pontoon type docks, the plating across the base of the wing walls in way of the pontoon gaps.

Structural plan of bottom caisson or pontoons.

Fresh water and oil fuel tanks.

A general arrangement plan, hydrostatic curves and the necessary data for calculating longitudinal strength (*see* 201) are also to be forwarded.

Working Instructions

107 On completion of the dock a copy of the Working Instructions for the dock is to be submitted for approval.

Definitions

108 The lifting capacity is the displacement in tonnes (tons) of the heaviest ship it is intended that the dock shall lift in normal service.

This lifting capacity shall be approved for classification, but the Society reserves the right to reduce it if the sinkage trials show that insufficient freeboard is available at the pontoon deck when this lifting capacity is added to the light displacement of the dock.

The light displacement shall include the structural weight of the dock complete with all machinery, cranes, equipment, full fresh water, fuel oil for the use of the dock, compensating ballast water (if required), and rest-water (as defined in 115).

109 The length L_D, in metres (feet), is the length of the bottom caisson or from the aft end of the aftermost pontoon to the fore end of the forward pontoon, but is exclusive of portable end platforms or swing bridges.

Amidships is to be taken as the middle of the length L_D.

110 The breadth B_D is the moulded breadth in metres (feet).

111 The depth D_D, in metres (feet), is the vertical distance from the lowest point of the bottom framing to the beam at outer wall of the uppermost deck (in 403 the top deck) to which the dock may theoretically be lowered in the water without sinking and without water penetrating into the compartments under this deck.

112 The safety deck is a watertight deck arranged at such a height below the top deck that when all compartments below the safety deck are flooded but with no load on the keel blocks, there is a reasonable freeboard from the top deck to the waterline. If air pipes are to be fitted under the safety deck, these are to be shown on the plans. This freeboard is generally to be not less than 1 m (3·25 ft), but may require to be amended depending on the service location of the dock.

Alternative arrangements to the fitting of a safety deck will be considered.

113 The freeboard to the pontoon deck at the centreline of the dock when supporting a ship whose displacement is the lifting capacity (as defined in 108) shall be not less than 300 mm (12 in). When the pontoon deck at the inner side walls is lower than at the centre, the freeboard to the pontoon deck at the inner side walls shall be not less than 75 mm (3 in) and the freeboard at the centre line shall be not less than 300 mm (12 in). These freeboards assume the travelling cranes are positioned to give no trim; the freeboard at level trim shall be such that when both cranes are moved to the forward end or to the after end of the dock, the pontoon deck shall not be submerged. These freeboards shall depend also on the location of the dock.

114 The length L_S, in metres (feet), is the length between perpendiculars of the shortest ship whose displacement is equal to the lifting capacity of the dock (as defined in 108), the breadth and draught of the ship being the maximum the dock can accommodate, and the block coefficient assumed to be 0,80. The length so calculated may have to be adjusted to give realistic proportions and, in general, the breadth B assumed need not be taken as greater than that corresponding to the following proportions:—

L_S (metres)	60	80	100	120	140	160	180	200	220	240	260	280
L_S (feet)	190	260	330	400	460	520	580	640	710	780	850	920
L_S/B	5,7	6,2	6,7	7,2	7,2	7,2	7,2	7,2	6,8	6,4	6,0	5,6

115 The rest-water is the ballast water in the tanks which the pumps cannot discharge.

116 Compensating ballast water is ballast water which may be used to control the deflection of the dock under longitudinal bending. Rest-water is not included in compensating ballast water.

Section 2

LONGITUDINAL STRENGTH

General

201 The longitudinal strength is to be calculated for the condition when the ship of length L_S (described in 114) is supported on the keel blocks, the centre of the ship's length being over the mid-length of the dock, and the freeboard at the pontoon deck is as described in 113. The level of ballast water is to be constant over the length L_D (as defined in 109).

Ship Weight Curve

202 The weight curve of the ship is to be taken as a rectangle with a superimposed parabola of half the area of the rectangle, the length of each area being L_S.

Bending Moments

203 The conditions described in 201 and 202 will result in a sagging bending moment, the units being tonne m (ton ft).

Modulus of Section

204 The material to be included in the calculation of the section modulus will be, for the caisson type dock, all continuous fore and aft material of the whole dock (i.e., wing walls structure and bottom pontoon).

For the pontoon type dock all continuous fore and aft material of the wing walls structure may be included together with the fore and aft material of the parts of the pontoon which are directly under the wing walls structure (i.e., material of pontoon lying between the lines of the inner walls is not included in the modulus calculation for this type of dock). At the section in way of the gap between pontoons, all continuous fore and aft material of the wing walls structure may be included, together with the horizontal plate across the base of the outer and inner walls, provided this plate extends longitudinally at least 2 m (78 in) over each pontoon.

The modulus of section calculation is to be included with the longitudinal strength data (*see* 106). The modulus units are to be in cm^3 (in^2 ft).

See also 207.

Permissible Stresses

205 When it is intended that the normal operation of the dock shall be with ballast water evenly distributed over its entire length, the stress in the bottom or deck, computed from the data in 203 and 204, is not to exceed 1400 kg/cm^2 ($8 \cdot 9$ ton/in^2).

206 When it is intended that the normal operation of the dock shall be by differential emptying of the ballast compartments, the stress with the ballast water suitably distributed shall be in accordance with 205.

In addition, the section modulus of the dock shall be not less than that required to ensure that the stress does not exceed 2200 kg/cm^2 (14 ton/in^2) when the ballast water (of the amount used in the condition described in the preceding sub-paragraph) is evenly distributed over the length of the dock.

207 An approximate value of the section modulus required to give the permissible stress may be derived from the formula:—

$$\text{Section modulus} = \frac{12\,500\ \text{L.C.}}{\text{f}}\left(\text{cL}_D - 0{,}917\ \text{L}_S\right)\ \text{cm}^3$$

$$\left(\frac{\text{L.C.}}{8\text{f}}\left(\text{cL}_D - 0{\cdot}917\text{L}_S\right)\ \text{in}^2\ \text{ft}\right)$$

where L.C. = lifting capacity of the dock, in tonnes (tons),

L_D = length of dock (*see* 109), in metres (feet),

L_S = length of ship (*see* 114), in metres (feet),

f = either 1400 kg/cm² or 2200 kg/cm² (8·9 ton/in² or 14 ton/in²) the permissible stress (*see* 205 and 206),

c = 1,0 for caisson type docks

and $c = a + \frac{nb}{n-1}$ for pontoon type docks,

where n = number of pontoons,

a = fraction of length of dock taken up by pontoons,

and b = fraction of length of dock taken up by gaps between pontoons.

208 Where the dock has to be towed in open waters from the port of construction to the port of operation, the total permissible stress en route is not to exceed 1730 kg/cm² (11 ton/in²). The designer's calculations of this stress are to be submitted. The wave conditions should assume a length of wave equal to L_D and height of wave the maximum expected to be encountered during the voyage in tow.

Extent of Scantlings

209 The scantlings of members included in the modulus calculation (*see* 204) shall be maintained over 20 per cent of the length of the dock L_D on each side of the longitudinal middle of the dock.

Deflection Meters

210 Two different types of deflection meter are to be fitted, the readings to be shown on an indicating board in the control rooms.

The meters shall be of the electrical and optical types and the deflections shall be obtained over the length of the dock L_D. The deflection corresponding to a stress of 1400 kg/cm² (8·9 ton/in²), when lifting the ship defined in 114, shall be stated in the Working Instructions. (*See* 107).

Alternative means of recording deflection will be specially considered.

Section 3

TRANSVERSE STRENGTH

General

301 The transverse strength is to be calculated, for the condition described in 201, at the centre of the length of the dock and towards the ends of the dock using the ship weight curve described in 202, and the modulus so required (*see* 303) is to be applied throughout the length of the dock.

Bending Moment

302 The bending moments on the transverses of the bottom caisson or pontoons are to be evaluated for the above condition and positions in tonne m (ton ft) units.

Modulus of Section

303 The material to be included in the calculation of the section modulus of a transverse will be the continuous athwart dock material associated with the transverse. The effective width of pontoon deck and of pontoon bottom plating to be taken with the transverse is to be calculated from the information given in D 5304.

Permissible Stresses

304 The compressive and tensile stresses computed from 302 and 303 are not to exceed 1730 kg/cm² (11 ton/in²).

Section 4

LOCAL STRENGTH

General

401 Plating and supporting stiffeners designed to meet the requirements of 205, 206, 208 and 304 may require to be increased to satisfy local strength requirements. Alternative means of computing scantlings to meet these requirements may be used when a copy of such calculations is to be submitted.

Tank Plating and Stiffeners

402 The thickness of plating in ballast tanks, oil tanks, fresh water tanks and sewage tanks is to be obtained from D 1907 and the scantlings of the stiffeners in these tanks are to be obtained from Chapter D, Table 40 of the 1967 Rules. For ballast tanks the pressure head to be used in association with the above is to be that obtained from an analysis of the hydrostatic curves.

Top Deck Plating

403 The thickness of plating for the middle 40 per cent of the length is to be as required for longitudinal strength. For 10 per cent of the length L_D at each end of the dock the thickness may be 6,5 mm (0·25 in), (with an increase of 3 per cent for every 25 mm (1 in) that the spacing of longitudinals exceeds 610 mm (24 in)), unless local conditions require a greater thickness. For the intermediate lengths (each of 20 per cent of the dock length) the thickness of the deck will be given proportionate values.

Top Deck Longitudinals

404 It is assumed the top deck will be stiffened longitudinally for the middle 40 per cent of the length. The scantlings of longitudinals will generally be those required to obtain the area necessary for the section modulus derived from longitudinal strength considerations but shall be not less than specified below for longitudinals at the ends.

For 10 per cent of the length L_D at each end of the dock the scantlings of the longitudinals are to be such that the stress under a loading of 1465 kg/m² (300 lb/ft²) does not exceed 1100 kg/cm² (7 ton/in²) the loading may require to be increased to suit the general arrangement of a particular dock.

The scantlings of the longitudinals in the intermediate length are to be intermediate between those required for the middle and end portions.

Safety Deck Plating

405 The thickness of plating of this deck, with the exception of those areas covered by 402, shall be in accordance with D 1907 using a depth 70 per cent of the height between decks (top of safety deck beam to top of top deck beam at side). This assumes a stowage rate of 1,39 m³/tonne (50 ft³/ton); where the stowage rate exceeds this value the depth to be used is to be increased proportionately. When air pipes project into the ballast tanks (*see* 501), it may be that the head corresponding to the maximum pressure in the air cushion will exceed the above value of the depth; in this case the depth used will be that corresponding to the air cushion pressure.

Safety Deck Beams

406 The beams under the safety deck, with the exception of those areas which are covered by 402, shall be in accordance with Chapter D, Table 40, of the 1967 Rules, and associated notes; the head H is to be used in this context being the value of the depth obtained as described in 405.

Framing

407 Framing of side walls, bottom, and pontoon deck shall be in accordance with Chapter D, Table 40, of the 1967 Rules, and associated notes, the head H being obtained from an analysis of the hydrostatic curves.

Transverses and Web Frames

408 The loadings on the deck transverses are to be in accordance with 402, 404 or 406, whichever is applicable. The width of deck supported by the transverse shall be the width between the inner and outer side walls and the length shall be the spacing of transverses.

The loading on deep side frames and bottom transverses shall be obtained from an analysis of the hydrostatic curves.

The permissible stress in transverses and deep frames shall be 787,5 kg./cm.² (5 ton/in²).

Cross Ties

409 Cross ties when fitted between the inner and outer wing walls shall be in accordance with D 4901, the value of h being obtained from an analysis of the hydrostatic curves.

Watertight Bulkhead Plating and Stiffeners

410 Pontoon centre line girder, when watertight, and watertight side girders shall be in accordance with 402. The strength of these items must also be considered in conjunction with the requirements of 412.

Non-Watertight Bulkheads

411 Non-watertight girders in pontoon. The thickness of plating is to be 7,5 mm (0·30 in). The scantlings of stiffeners are to be determined from D 1414 to D 1418, the load P being based on the head of water obtained from an analysis of the hydrostatic curves, to which the pontoon deck and bottom plating is subjected.

The strength of these items must also be considered in conjunction with the requirements of 412.

Keel Blocks and Supporting Structure

412 The loading to be taken (over the whole length of the dock) by the keel blocks and supporting structure shall be $\frac{1{,}167}{L_S}$ × the lifting capacity, in tonne m (ton ft).

Platforms Extending from Ends of Dock

413 The loading on these structures is assumed to be 586 kg/m² (120 lb/ft²). If a heavier loading is anticipated or required, the plans are to be marked accordingly.

Swing Bridges at End of Dock

414 The loading on this connecting bridge is assumed to be 366 kg/m² (75 lb/ft²). If a heavier loading is anticipated or required, the plan is to be marked accordingly.

Section 5

ADDITIONAL ITEMS

Air Pipes under Safety Deck

501 The maximum draught of the dock (*see* 112) may be controlled by fitting air pipes under the safety deck and/or the centre pontoons. The length of these pipes will be dependent on the extent of the cushion of air desired. The pipes are to be of substantial thickness and rigidly supported in place.

Cranes

502 The structure of travelling cranes on the top deck is not included in the Society's survey unless specially desired.

The all-up weight of cranes, arrangement of wheels and rails are to be indicated on the plans, so that local strength requirements due to these loads may be taken into account.

Manholes

503 Sufficient manholes are to be cut in the safety deck, pontoon deck, transverses and girders in pontoons to provide adequate ventilation and access to all parts of the structure. The edges of holes are to be smooth. *See also* D 934.

Cofferdams

504 Compartments carrying oil are to be separated by cofferdams from those carrying fresh water. Cofferdams are to be suitably ventilated.

Coating

505 Particular attention is to be paid to the coating of the underwater portion of the dock. Full particulars are to be submitted for approval.

Section 6

TESTING

General

601 Each ballast tank, oil tank, and fresh water tank and cofferdam is to be separately tested by filling with water to the test head.

When water testing on the building berth may be undesirable, testing may be carried out afloat, provided any riveted shell seams in the bottom plating are tested with a high pressure hose on the berth. The testing afloat is to be so arranged that each tank can successively be examined whilst being subjected to a head of water equal to the maximum operational head as found from the hydrostatic curves.

When a preservative coating is to be applied to the internal structure of a tank, the water testing may take place after the application of the preservative, provided the structure is carefully examined to ensure that all welding and structural stiffening are completed prior to the application of the coating, and any riveted shell seams are tested with a high pressure hose on the berth before coating. The hose test of the riveted seams may be carried out from the outside to avoid wetting the tank structure.

The cause of any discoloration or disturbance of the coating is to be ascertained and any deficiencies repaired.

Compartments above the safety deck may be tested to an air pressure of 0,25 kg/cm² (3·5 lb/in²). Precautions are to be taken to ensure that this pressure is not exceeded.

Test Head

602 The test head for ballast tanks, as mentioned in the first sub-paragraph of 601 is to be 500 mm (20 in) above the top deck at side, but need not exceed twice the pressure head determined in accordance with 402.

Sinkage Trials

603 On the completion of the dock, sinkage trials shall be carried out in the presence of the Society's Surveyor. Fresh water tanks and the dock's fuel tanks shall be full, but ship-oil tanks are to be empty. The travelling cranes may be so positioned that the draughts forward and aft are equal. The density of the water shall be recorded.

(*a*) *Normal Condition.* All ballast water shall be emptied as far as possible, only rest-water remaining. The draughts forward and aft, port and starboard, shall be recorded. The readings on deflection meters shall be taken. The deflection of the dock along the top of keel blocks shall be measured.

Adjustment of the meters shall then be made, if necessary, so that they record this built-in permanent deflection in the normal condition. The light displacement shall be evaluated from these readings, and to obtain the light displacement, as defined in 108, the weight of any compensating ballast water must be added.

(*b*) *Sagging Condition*. Equal amounts of water shall be admitted to corresponding tanks on either side of the middle of the length, the depths increasing until the greatest depth is in the tanks at the middle of the length. The sagging bending moment so produced shall equal that evaluated in 203. The deflection meter readings shall be recorded and, by allowing for the permanent deflection, *see* sub-para. (*a*), the sagging deflection will be obtained.

Alternative arrangements to those described in (*b*) above will be specially considered.

604 When estimating the quantities of ballast water for 603 (*b*), the permissible difference in height of ballast water in adjacent compartments shall not exceed the pressure head for the compartments as laid down in 402.

Section 7

MACHINERY INSTALLATIONS

General

701 Items of machinery, such as boilers, pressure vessels, auxiliary engines, compressors, pumps, etc., essential to the operation of a floating dock are to be constructed and installed in general accordance with the relevant requirements of the Rules.

702 Fire extinguishing appliances, pumping arrangements, oil fuel and other piping systems are to be provided in accordance with the Rules so far as they may be applicable to floating docks.

703 The arrangements for discharging water ballast are to be such that not less than two pumps are available for pumping out each buoyancy compartment.

Electrical Installations

704 Electrical equipment constructed in accordance with the Rules will be accepted. Alternatively, consideration will be given to the acceptance of equipment constructed in accordance with a national or international standard for industrial equipment. In the latter case due consideration is to be given to the ambient temperature and other ambient conditions expected in service and the necessary adjustments made to such items as permissible temperature rise.

705 In all other respects, e.g., the system of distribution, the installation is to comply with normal good electrical engineering practice and Chapter M is to be used as a guide for this purpose.

706 The following is to be carried out by the Surveyors and in accordance with Chapter M:—

(i) Inspection and testing of electrical equipment.
(ii) Installation of electrical equipment.
(iii) Final testing of the electrical installation.

Plans

707 All necessary plans are to be submitted for approval before work is commenced.

Section 8

PERIODICAL SURVEYS

Annual Surveys

801 Docks should be surveyed afloat at intervals of approximately one year.

Special Surveys

802 Docks are to be subjected to Special Surveys at four-yearly intervals, the first four years from the date of build and thereafter from the date of the previous Special Survey.

PERIODICAL SURVEY REGULATIONS

HULL

Annual Surveys

803 The Surveyor is to satisfy himself as to the efficient condition of the following:—

Pontoon, safety and top working decks, exposed inner walls, shell plating above the light waterline, keel blocks and their foundations, casings, skylights, companionways and ladders, hatchways and manholes with their closing and securing arrangements, exposed self-docking connections, hinged gangways, mooring attachments, air pipes and overboard scuppers and discharges, guard rails and stanchions and rubbing fenders.

Special Surveys

804 The full requirements of an Annual Survey are to be complied with together with the following:—

The spaces between the safety and top working decks are to be cleared and cleaned as necessary and examined, lining and pipe casings are to be removed as required.

805 The Surveyor may require to ascertain by drilling or other approved means the thickness of the materials in any portion of the structure where signs of wastage are evident or wastage is normally found. Any parts of the structure which are found defective or materially reduced in scantlings are to be made good by materials of the approved scantlings and quality. Surfaces are to be recoated as necessary.

806 Where the inner surface of the bottom plating is covered with cement, asphalt or other composition the removal of this covering may be dispensed with, provided it be inspected, tested by beating or chipping, and found sound and adhering satisfactorily to the steel.

Pontoon and side wall tanks are to be cleaned and examined internally and tested by a head sufficient to give the maximum pressure that can be experienced in service.

807 Wood deck sheathing is to be examined and if decayed or rot is found or the wood is excessively worn it should be renewed. Attention is to be given to the condition of the plating under the sheathing or other deck covering. If it is found that such coverings are broken or not adhering closely to the plating, sections should be removed as necessary to ascertain the condition of the plating.

808 For floating docks not more than 15 years old, oil fuel tanks forming part of the main structure need not be examined internally. When examining tanks internally the Surveyor is to satisfy himself as to the condition of the pump suctions.

809 The Owners' proposals for examination of the underwater portion of the dock are to be submitted for consideration.

810 At the first Special Survey after the dock is 24 years old and at every 12 years thereafter or at the next Special Survey after the expiration of the latter period, the full requirements of a Special Survey stated above are to be complied with together with the following:—

In addition to the drilling required to ascertain local wastage the outside plating of the walls and pontoons are to be gauged by drilling or other approved means to determine the amount of any general diminution in thickness. The gauging is to be done in at least two places in each strake of plating on each side within the amidship half length.

All paint and rust is to be entirely removed before the plates are gauged by the Surveyor and the actual thicknesses are to be reported in detail. Where drilled plates are renewed the thickness of adjacent plates in the same strake should be reported.

MACHINERY INSTALLATION

811 For maintenance of class the boilers, machinery and electrical installations are to be submitted to periodical surveys in accordance with the relevant requirements of Chapters B and C, so far as these are applicable.

812 Where practicable, all sea connections should be opened up as part of the machinery survey but the Committee will be prepared to consider alternative proposals having regard to the circumstances of each case, provided full particulars are submitted.

25th January, 1968

R (G)—GUIDANCE NOTES ON PROPELLER-HULL CLEARANCES

Symbols

101 D = propeller diameter, in metres (feet).
R = propeller radius, in metres (feet).
L = length of ship, in metres (feet).

General

102 The following recommendations indicate the minimum clearances between the propeller and sternframe, rudder or hull that should be provided to minimise the possibility of propeller excited vibration.

SINGLE SCREW SHIPS

103 The clearances between the propeller and the rudder or sternframe should not be less than given in Table R (G) 1.1.

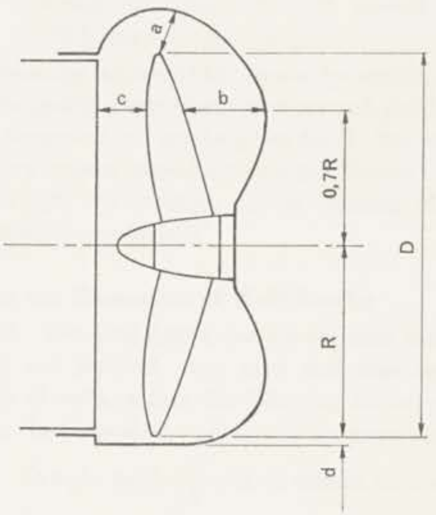


TABLE R (G) 1.1

NUMBER OF BLADES	a*	b*	c*	d
3	$1{,}2k_1D$	$1{,}8k_1D$	$0{,}12D$	$0{,}03D$
4	$1{,}0k_1D$	$1{,}5k_1D$	$0{,}12D$	$0{,}03D$
5	$0{,}85k_1D$	$1{,}275k_1D$	$0{,}12D$	$0{,}03D$
6	$0{,}75k_1D$	$1{,}125k_1D$	$0{,}12D$	$0{,}03D$

where

$$k_1 = \left(0{,}1 + \frac{L}{3050}\right)\left(\frac{2{,}56\,C_bH}{L^2} + 0{,}3\right)$$

$$\left(k_1 = \left(0\cdot1 + \frac{L}{10\,000}\right)\left(\frac{28\,C_b\,H}{L^2} + 0\cdot3\right)\text{ British}\right)$$

C_b = moulded block coefficient at load draught.

H = maximum designed shaft horse power.

*NOTE.—In no case should "a" be less than $0{,}10D$, "b" less than $0{,}15D$, or "c" less than the maximum thickness of the rudder. The thickness is to be measured at the $0{,}7R$ line above the shaft centre line.

TWIN SCREW SHIPS

104 The propeller tip-hull clearance should not be less than:—

3 blades: $1{,}2k_2D$ but not less than $0{,}2D$
4 blades: $1{,}0k_2D$ but not less than $0{,}2D$
5 blades: $0{,}85k_2D$ but not less than $0{,}16D$
6 blades: $0{,}75k_2D$ but not less than $0{,}16D$

The clearance between the propeller and the shaft brackets or bossing should not be less than:—

3 blades: $1{,}2k_2D$ but not less than $0{,}15D$
4 blades: $1{,}0k_2D$ but not less than $0{,}15D$
5 blades: $0{,}85k_2D$ but not less than $0{,}15D$
6 blades: $0{,}75k_2D$ but not less than $0{,}15D$

where

$$k_2 = \left(0{,}1 + \frac{L}{3050}\right)\left(\frac{1{,}28\,C_b\,H}{L^2} + 0{,}3\right)$$

$$\left(k_2 = \left(0\cdot1 + \frac{L}{10\,000}\right)\left(\frac{14\,C_b\,H}{L^2} + 0\cdot3\right)\text{ British}\right)$$

C_b = moulded block coefficient at load draught,

H = maximum total designed shaft horse power installed.

16th January, 1969

R (H)—PROVISIONAL RULES FOR REPAIRS BY WELDING TO STEEL CASTINGS FOR CRANKSHAFTS

Section 1

General

101 Welded repairs are only to be undertaken when:—

(a) the repairs are considered to be necessary and are approved by the Surveyor. Consideration must be given first to the blending of grooves formed by the removal of shallow defects, or to the machining of a surface where there is excess metal on the Rule dimension.

(b) the specified maximum tensile strength of the steel is not in excess of 65 kg/mm² (41 ton/in²).

(c) the maximum carbon content and the maximum carbon equivalent do not exceed 0,30% and 0,65% respectively (*see* Q 513).

Generally, approval for repairs by welding will only be given to rectify areas where random and accidental defects arise. Approval will not be given for (1) the rectification of repetitive defects caused by improper foundry technique or practice; (2) the building up by welding of surfaces or large shallow depressions.

Position and Dimensions of Weld Repairs

102 Provided Surveyors are satisfied that repairs by welding are justified, they may authorise repairs to the surfaces of webs, within the following limits:—

(a) In general, the volume of the largest groove which is to be welded is not to exceed $3{,}2\,t\,cm^3\left(\frac{t}{2}\,in^3\right)$ where t is the web axial thickness, in cm (in), The total volume of all grooves which are to be welded is not to exceed $9{,}6\ t\ cm^3$ ($1\cdot5\ t\ in^3$) per web.

(b) The welds do not extend within the cross-hatched zones marked on Figs. R (H) 1.1 and R (H) 1.2 for fully-built and semi-built throws, respectively.

(c) Larger repairs on balance weights may be permitted at the discretion of the Surveyor provided such repairs are wholly contained within the balance weight and do not affect the strength of the web.

103 Weld repairs may also be authorised in the surface of the bore for the journal (or pin) within the following limits:—

(a) In general, the welds are to be not less than 125 mm (5 in) apart.

(b) The welds are not located within circumferential bands of $\frac{t}{5}$ from the edges of the bores, nor at any position within the inner 120° arc of the bores, as cross-hatched on Figs. R (H) 1.1 and R (H) 1.2.

(c) The volume of the largest weld is not more than about $1{,}1\ t\ cm^3\left(\frac{t}{6}\,in^3\right)$ where t is the web axial thickness at the bore, in cm (in), and not more than three welds are to be made in any one bore surface.

104 At the discretion of the Surveyor, the size of a groove may be increased somewhat beyond the limiting sizes given in 102 (a) or 103 (c) if the removal of further metal will facilitate welding.

Repair Procedure

105 All castings are to be given a preliminary refining heat treatment prior to the commencement of weld repairs.

Only experienced welders are to make the repairs and, at any time, the Surveyors may require a welder to demonstrate his ability to make a sound weld.

106 After all defective material has been removed from a region, and this has been proved in the presence of the Surveyor by magnetic particle inspection or other suitable method, the depression may be suitably shaped to allow good access for welding.

107 Before welding, the material is to be preheated to a temperature of not less than 200°C. Where possible preheating should be carried out in a furnace. The preheat temperature is to be maintained until welding is completed and preferably until the casting is charged to the furnace for post-weld heat treatment.

108 Welds are to be made by the electric arc process in the downhand (flat) position using low hydrogen electrodes which will produce a deposited metal in no way inferior in properties to the parent metal.

109 On completion of the repairs the casting is to be given a suitable heat treatment, which is to consist of either full annealing or normalising and tempering. Where small isolated defects are revealed after completion of full heat treatment as above, welding repairs followed by a stress

relieving treatment within the range 630 to 660°C may be permitted.

110 Welds are to be dressed smooth by grinding and proved by magnetic particle inspection. The surfaces of the welds and adjacent parent steel are to be free from harmful defect.

Documentation

111 The foundry is to provide Surveyors with a statement and/or sketch detailing the extent and location of the welded repairs made to each casting together with details of the heat treatment carried out at all stages.

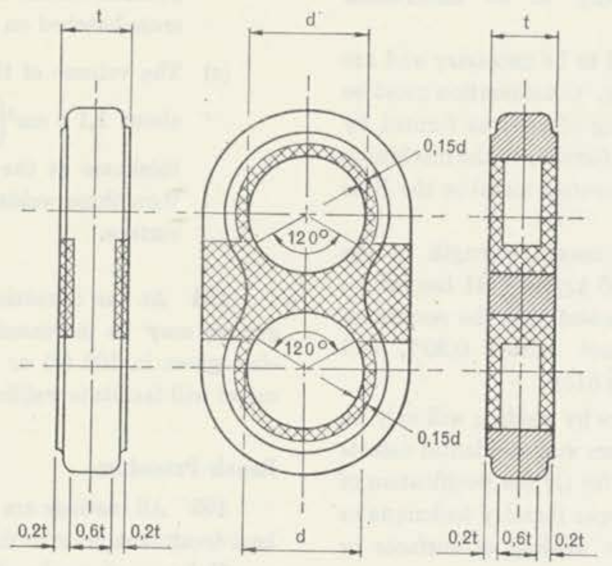


Fig. R (H) 1.1

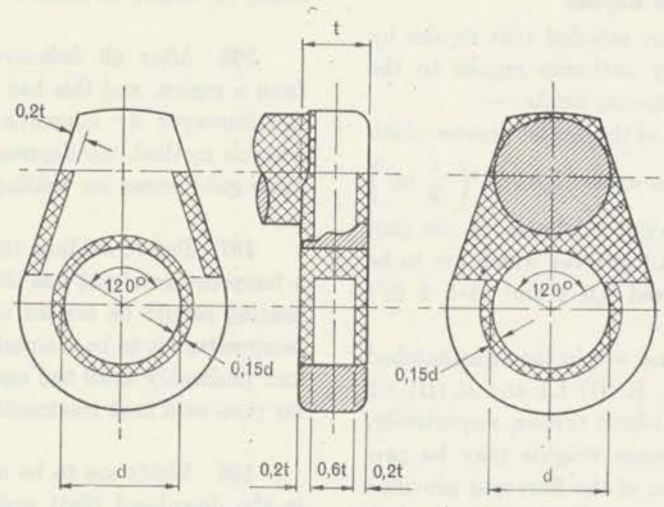


Fig. R (H) 1.2

16th June, 1966

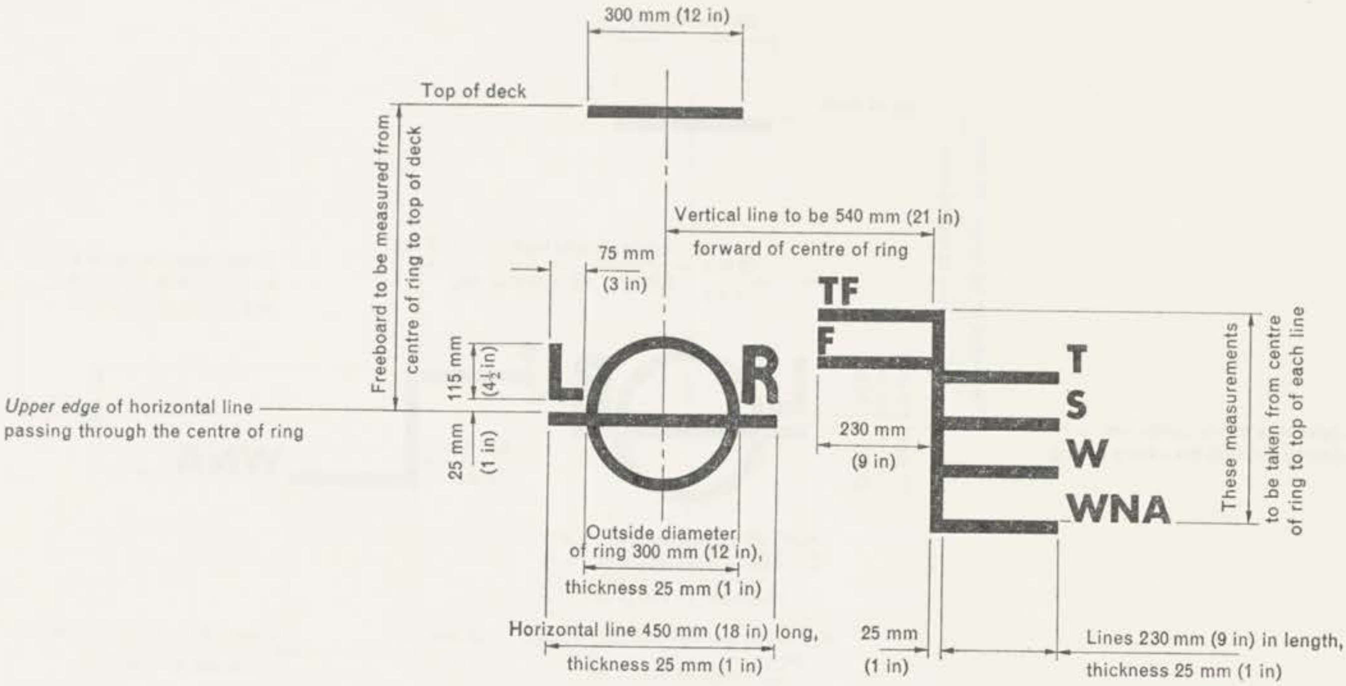
By Order of the Committee,

J. HUXSTER, *Secretary.*

ASSIGNMENT OF FREEBOARD

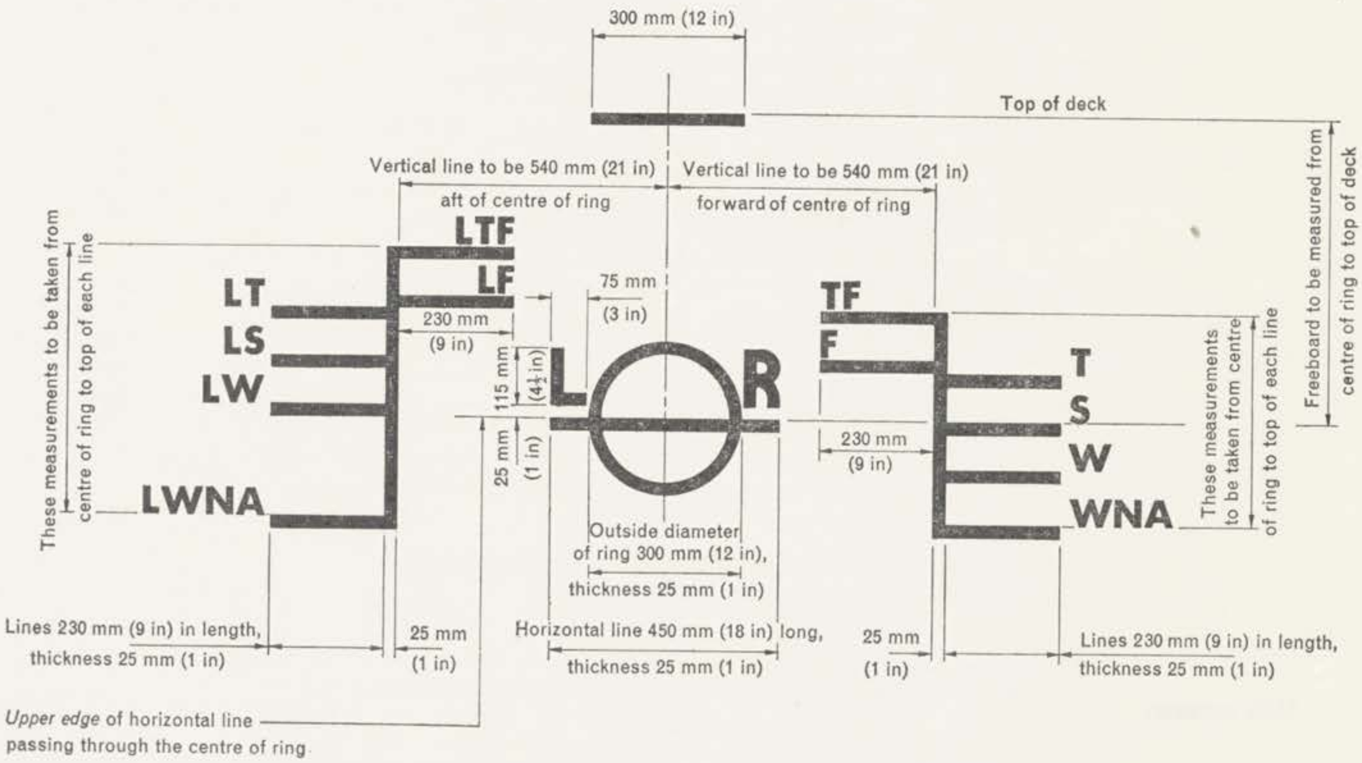
The Committee of Lloyd's Register are authorised to assign freeboards to British ships and to ships registered in other countries. Forms of application for the assignment of freeboard can be obtained from the London Office, or other offices of the Society.

FREEBOARD MARKING FOR SHIPS



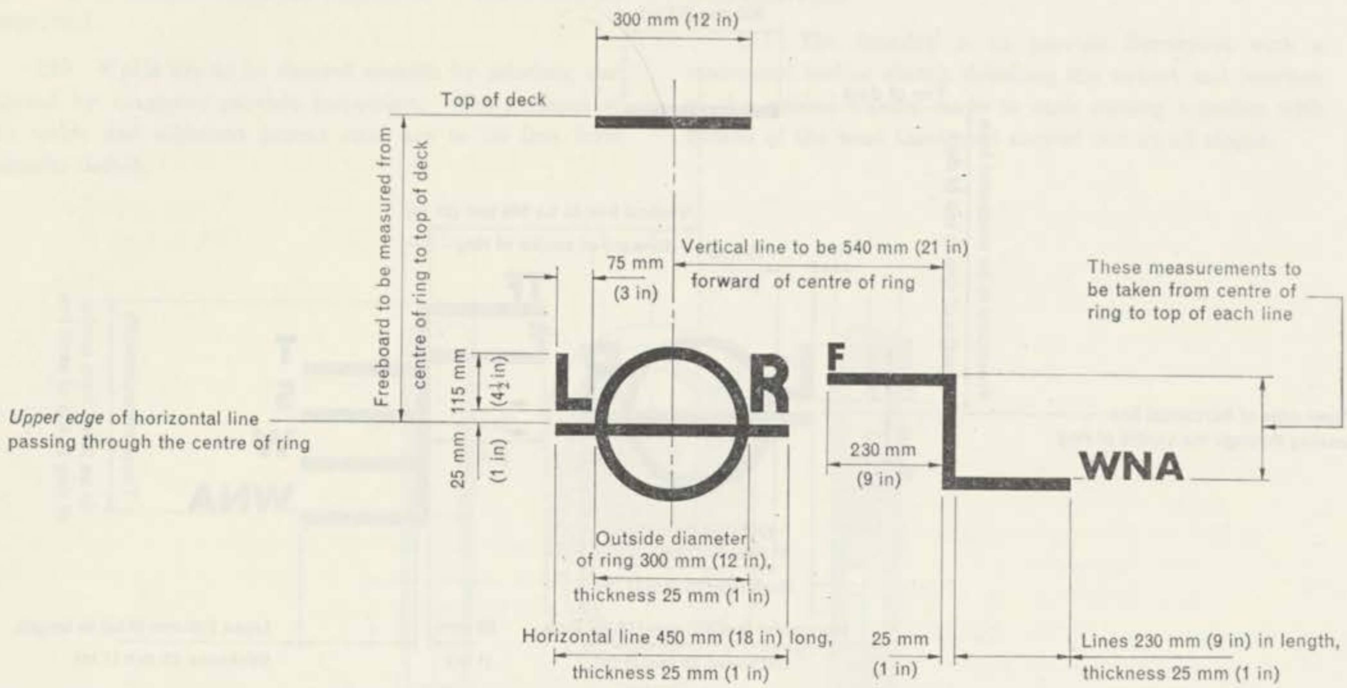
The centre of the ring is to be placed on both sides of the ship amidships, i.e., at the middle of the length (L) as defined in the International Load Line Convention, 1966. The ring, lines and letters are to be painted in white or yellow on a dark ground or in black on a light ground. They are also to be permanently marked on the sides of the ship to the satisfaction of the Administration. The marks are to be plainly visible and, if necessary, special arrangements are to be made for this purpose. Ships over 100 m (328 ft) in length are not required to be marked with the WNA line.

FREEBOARD MARKING FOR SHIPS CARRYING TIMBER DECK CARGOES



The centre of the ring is to be placed on both sides of the ship amidships, i.e., at the middle of the length (L) as defined in the International Load Line Convention, 1966. The ring, lines and letters are to be painted in white or yellow on a dark ground or in black on a light ground. They are also to be permanently marked on the sides of the ship to the satisfaction of the Administration. The marks are to be plainly visible and, if necessary, special arrangements are to be made for this purpose. Ships over 100 m (328 ft) in length are not required to be marked with the WNA line. For such ships the LWNA line is to be level with the W line.

FREEBOARD MARKING FOR SAILING SHIPS



The centre of the ring is to be placed on both sides of the ship amidships, i.e., at the middle of the length (L) as defined in the International Load Line Convention, 1966. The ring, lines and letters are to be painted in white or yellow on a dark ground or in black on a light ground. They are also to be permanently marked on the sides of the ship to the satisfaction of the Administration. The marks are to be plainly visible and, if necessary, special arrangements are to be made for this purpose.

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LLOYD'S REGISTER OF SHIPPING

January, 1971

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